

**FINAL**

**Intrinsic Remediation  
Engineering Evaluation/Cost Analysis Addendum  
for Site SS27/XYZ**



**Dover Air Force Base  
Dover, Delaware**

**Prepared For**

**Air Force Center for Environmental Excellence  
Technology Transfer Division  
Brooks Air Force Base, Texas  
San Antonio, Texas**

**and  
Dover Air Force Base  
Dover, Delaware**

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**September 1999**

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21 September 1999

Mr. Jerry Hansen  
Technical Program Manager  
AFCEE/ERT  
3207 North Road, Bldg. 532  
Brooks AFB, TX 78235-5363

Subject: Submittal of the Final Intrinsic Remediation Engineering Evaluation/Cost Analysis Addendum for Site SS27/XYZ, Dover Air Force Base, Delaware (Contract F41624-92-D-8036-0006)

Dear Mr. Hansen:

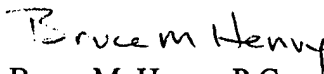
Enclosed please find two copies of the September 1999 Final Intrinsic Remediation Engineering Evaluation/Cost Analysis (EE/CA) Addendum for Site SS27/XYZ, Dover Air Force Base (AFB), Delaware. This report was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Dover AFB.

The intent of the Addendum was to evaluate the effectiveness of natural attenuation in remediating fuel contamination in groundwater at Site SS27/XYZ. The draft Addendum was submitted to AFCEE in August 1999. Comments on the draft Addendum were received from AFCEE as reviewed by Jon Atkinson (dated 17 September 1999). Responses to these comments were prepared by Parsons ES and are attached to this Addendum.

If you have any questions or comments regarding this package, please do not hesitate to contact me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

  
Bruce M. Henry, P.G.  
Project Manager

Enclosures

c.c. Joan Deramo – Dover AFB (two copies)  
Mr. Don Kampbell – USEPA NRMRL (two copies)

**FINAL  
INTRINSIC REMEDIATION  
ENGINEERING EVALUATION/ COST ANALYSIS ADDENDUM**

**for**

**SITE SS27/XYZ  
DOVER AIR FORCE BASE  
DOVER, DELAWARE**

**September 1999**

**Prepared for:**

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE  
BROOKS AIR FORCE BASE  
SAN ANTONIO, TEXAS**

**AND**

**DOVER AIR FORCE BASE  
DOVER, DELAWARE**

**Prepared by:**

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## LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AMC	Air Mobility Command
BTEX	benzene, toluene, ethylbenzene, and xylenes
CO <sub>2</sub>	carbon dioxide
DO	dissolved oxygen
EE/CA	Engineering Evaluation/ Cost Analysis
ft/day	feet per day
ft/ft	foot per foot
ft/yr	feet per year
Fe <sup>+3</sup>	ferric iron
Fe <sup>+2</sup>	ferrous iron
IRP	Installation Restoration Program
HAZWRAP	Hazardous Waste Remedial Actions Program
JP-4	jet fuel
LNAPL	light non-aqueous phase liquid
LTM	long-term monitoring
MTBE	methyl tertiary-butyl ether
µg/L	micrograms per liter
mg/L	milligrams per liter
mV	millivolts
NRMRL	National Risk Management Research Laboratory
NW/SE	northwest to southeast
ORP	oxidation/reduction potential
Parsons ES	Parsons Engineering Science, Inc.
redox	reduction/oxidation
RI/FS	remedial investigation/feasibility study
SAIC	Science Applications International Corporation
SPTG	Support Group
TMB	trimethylbenzene
TOC	total organic carbon
TRC	Tracer Research Corporation
USEPA	United States Environmental Protection Agency

## 1.0 INTRODUCTION

This addendum was prepared for the Air Force Center for Environmental Excellence (AFCEE) by Parsons Engineering Science, Inc. (Parsons ES) as an update to the *Final Intrinsic Remediation Engineering Evaluation/Cost Analysis (EE/CA) for Site SS27/XYZ* at Dover Air Force Base (AFB) in Dover, Delaware (Parsons ES, 1996, hereafter referred to as the "EE/CA"). The EE/CA was conducted to evaluate intrinsic remediation (natural attenuation) of groundwater contaminated by petroleum hydrocarbons for Installation Restoration Program (IRP) Site SS27/XYZ, the fuel pump station (Building 950), at Dover AFB. The EE/CA sampling event was conducted in April 1994. This addendum summarizes the results of second and third sampling events conducted in September 1997 and February 1999 as part of the continuing evaluation of intrinsic remediation at the site. Results and predictions presented in the EE/CA are used as the basis for comparison.

In the EE/CA, comparison of benzene, toluene, ethylbenzene, and xylenes (BTEX); electron acceptor; and biodegradation byproduct isopleth maps for the site indicated strong qualitative evidence of biodegradation of BTEX compounds. Geochemical data strongly suggested that aerobic biodegradation of fuel hydrocarbons was occurring at the site. In addition, the data also suggested that anaerobic biodegradation was occurring via sulfate reduction, denitrification, and iron reduction. Patterns observed in the distribution of fuel hydrocarbons, electron acceptors, and biodegradation byproducts indicated that biodegradation was reducing dissolved BTEX concentrations in site groundwater.

While the results presented in the EE/CA indicated that intrinsic remediation of BTEX compounds was occurring at the site, it was suggested that without engineered source reduction, intrinsic remediation alone might not be sufficient to ensure protection of human health and the environment. This was due to a plume of mobile and residual light non-aqueous phase liquid (LNAPL) present in the subsurface.

Therefore, the Air Force recommended that engineered source removal (i.e., bioslurping and bioventing) be implemented in conjunction with intrinsic remediation, long-term monitoring (LTM), and institutional controls. During 1995, AFCEE and Dover AFB conducted a bioslurping pilot study at the site to evaluate the effectiveness of this technology. Based on these test results, Dover AFB designed a bioslurping system and planned to install that system at the site in April 1996. To date, the system has not been installed. Therefore, natural attenuation processes are acting alone to reduce BTEX mass and concentration.

### 1.1 Scope and Objectives

The primary objective of this addendum is to evaluate changes in (1) concentrations of dissolved BTEX, (2) BTEX plume extent, and (3) natural attenuation mechanisms that are responsible for reducing BTEX mass and concentration between April 1994 and February 1999. Data collected in April 1994 for the EE/CA are used as a baseline for comparison. Groundwater samples were collected in September 1997 and February 1999 by researchers from the United States Environmental Protection Agency (USEPA)

National Risk Management Research Laboratory (NRMRL) Subsurface Protection and Remediation Division. Samples were collected from 14 existing monitoring points in September 1997, and from 12 existing and replacement monitoring wells/points in February 1999. Monitoring wells/points with free product were not sampled in 1997 and 1999. In addition, several wells/points did not yield sufficient groundwater for sampling in 1997 or 1999 due to low water table elevations.

## 1.2 Site Background

Dover AFB is located in Kent County, Delaware. The Base occupies approximately 4,000 acres of land including annexes, easements, and leased property. The land surrounding the Base is relatively flat. The surrounding properties include light commercial and residential properties, croplands, and wetlands. The St. Jones River is located about 2,500 feet southwest of Site SS27/XYZ, and Delaware Bay is located approximately 4 miles to the east of Dover AFB.

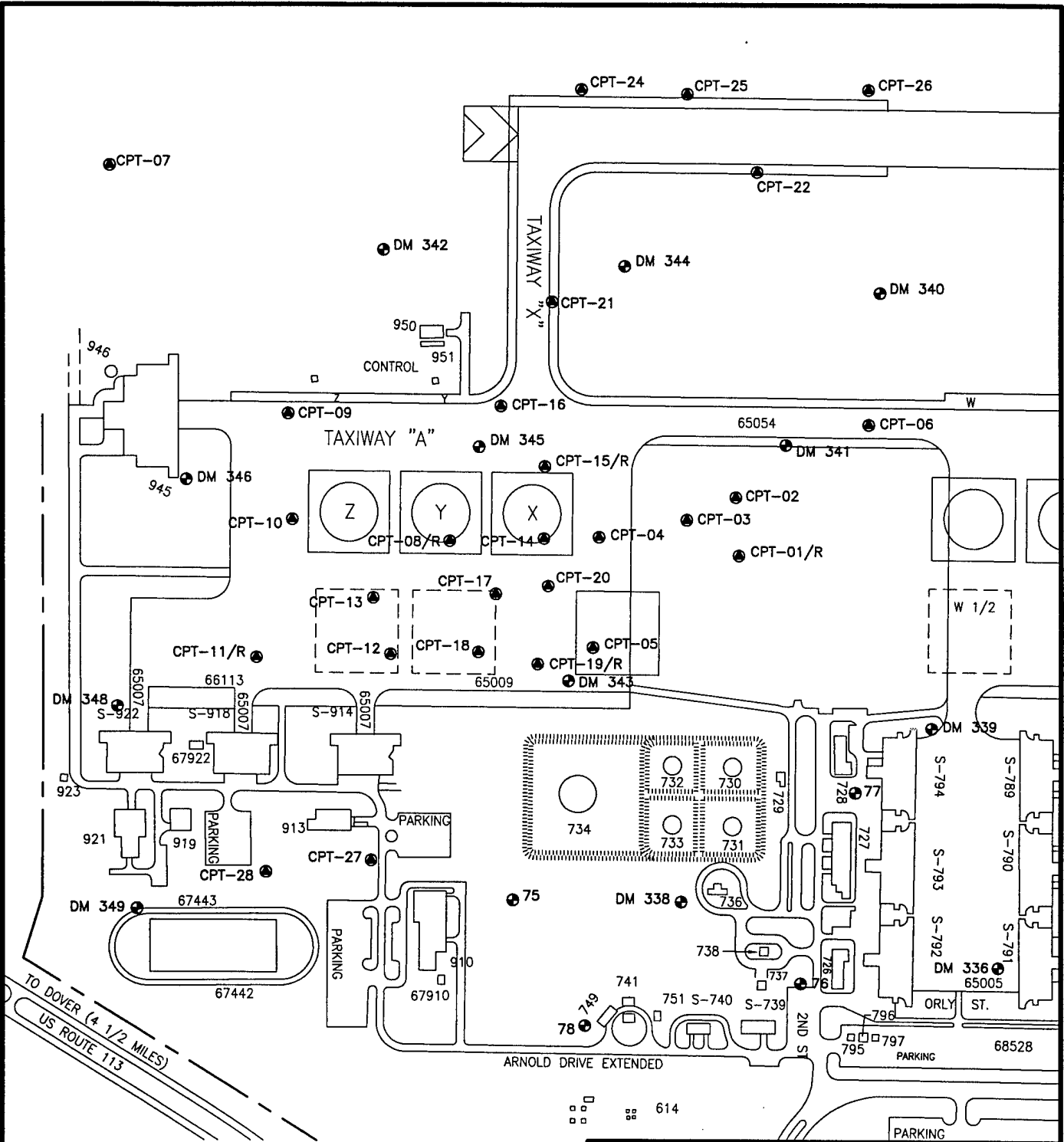
The Base has operated since 1941, and is currently a member of the Air Mobility Command (AMC), which hosts the 436<sup>th</sup> Support Group (SPTG). The Base's main mission is to provide global strategic airlift capability, primarily with C-5 Galaxy transport aircraft.

Site SS27/XYZ is located in the northwestern corner of the Base at the northwest end of the northwest to southeast (NW/SE) runway and east of US Route 113 (Figure 1). The site includes the northwest apron, the northwest corner of the NW/SE runway, the former X, Y, and Z refueling pads (currently known as the AA, BB, and CC refueling pads), and all adjacent areas that contain monitoring wells/points. Jet fuel (JP-4) leaks emanating from subsurface fuel lines and/or ancillary equipment have contaminated soil and groundwater at Site SS27/XYZ. Building 950 has served as a fuel pumping station for refueling pads X, Y, and Z since fueling operations began. Underground fuel lines are used to transfer jet fuel from the fuel pump station at Building 950 to the fuel hydrants at pads X, Y, and Z. Site SS27/XYZ was included in the IRP process at the Base because Base personnel reported fuel floating on rainwater that collects in control pits in front of Building 950 (Science Applications International Corporation (SAIC), 1989).

Soil and groundwater contamination was detected at Site SS27/XYZ in June 1984 during preliminary site characterization activities conducted as part of the Phase II IRP investigations (SAIC, 1986). A second soil and groundwater investigation was conducted at the site in 1989 (SAIC, 1989). Additional site characterization activities, including a soil gas survey, soil borings, monitoring well installations, and soil and groundwater sampling, were conducted at Site SS27/XYZ (Dames & Moore and Hazardous Waste Remedial Actions Program (HAZWRAP), 1993). Results of the study indicated areas of petroleum hydrocarbon contamination along fuel lines, and the distribution of fuel hydrocarbons also suggest that fuel constituents extend beneath the fueling pads. Other tests performed at the site as part of a Base-wide remedial investigation/feasibility study (RI/FS) program included leak tests on all underground JP-4 pipelines in 1991 (Tracer Research Corporation (TRC), 1991); and a Base-wide ecological risk assessment conducted in 1993 (HAZWRAP, 1993). Site SS27/XYZ has been the subject of two previous environmental investigations in which a groundwater



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**FIGURE 1**

## SITE FEATURES AND SAMPLING LOCATIONS

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

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contaminant plume was identified. Dissolved constituents included benzene, ethylbenzene, xylene, and 1,4-dichlorobenzene (Dames & Moore and HAZWRAP, 1993), resulting from the release of JP-4 fuel into the subsurface.

## 2.0 MONITORING RESULTS

Researchers from the USEPA NRMRL collected groundwater samples from 14 monitoring wells/points in September 1997, and from 12 monitoring wells/points in February 1999. Analytical methods used for groundwater sample analyses are summarized in Tables 1A and 1B. Prior to the 1999 sampling event, six monitoring points had to be replaced because the original monitoring points had been damaged by paving operations at the site. Monitoring point construction data for the six replacement points are summarized in Table 2. Groundwater samples were analyzed in the field for dissolved oxygen (DO), temperature, pH, conductivity, oxidation/reduction potential (ORP), alkalinity, carbon dioxide (CO<sub>2</sub>), sulfide, and ferrous iron (Fe<sup>2+</sup>). Additional sample volume was analyzed at the USEPA NRMRL in Ada, Oklahoma for total fuel carbon (1997 only), BTEX, trimethylbenzenes (TMBs), methyl tertiary-butyl ether (MTBE) (1999 only), methane, ethane and ethene (1999 only), nitrate + nitrite, ammonia, chlorides, total organic carbon (TOC), and sulfate. Prior to purging and sampling each well/point, groundwater levels were measured to the nearest 0.01 foot in 1997, and to the nearest 0.1 foot in 1999.

### 2.1 Flow Direction and Gradient

Depth to groundwater was measured in 4 monitoring wells in 1997 and in 16 monitoring wells/points in February 1999. Table 3 summarizes groundwater elevations measured in April 1994, September 1997, and February 1999. Isopleth maps for groundwater elevations measured in April 1994 and February 1999 are presented in Figure 2. Where wells/points are clustered with varied aquifer intervals, only wells/points reflecting the shallowest groundwater elevation were used to construct the contour intervals for April 1994. There are insufficient data to contour water table elevations for 1997 or 1999. The predominant direction of shallow groundwater flow at the site is to the southwest. Groundwater elevations observed in some wells were anomalous and were not used in the construction of the water table surface map. Anomalous water levels in some areas of the site are likely the result of perched water due to discontinuous, low permeability silty clay layers present beneath the site (Parsons ES, 1996).

Water levels were lower in all wells/points measured from April 1994 to September 1997, and from September 1997 to February 1999. Changes in water elevations for the period between April 1994 and February 1999 are shown for selected wells in Figure 3. Decreases in water elevations between April 1994 and February 1999 ranged from 3.83 feet (DM344S) to 7.09 feet (DM342S), and averaged 5.7 feet (as measured in 12 wells). The cause of the drop in groundwater levels is unknown, but may result from changes in annual precipitation rates or man-made features.

The average hydraulic gradient toward the southwest from the source area was 0.0021 foot per foot (ft/ft) in April 1994. Although the water table experienced a

**TABLE 1A**  
**SUMMARY OF GROUNDWATER ANALYTICAL METHODS**  
**SEPTEMBER 1997**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Analyte	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation/Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe <sup>2+</sup> )	Colorimetric, Hach® Method 8146 or equivalent	F
Hydrogen Sulfide	Colorimetric, Hach® Method 8131 or equivalent	F
Carbon Dioxide	Titrimetric, Hach® Method 1436-01 or equivalent	F
Alkalinity (Carbonate [CO <sub>3</sub> <sup>2-</sup> ] and Bicarbonate [HCO <sub>3</sub> <sup>-</sup> ])	Titrimetric, Hach® Method 8221 or equivalent	F
Nitrate + Nitrite	Environmental Protection Agency Method 353.1	L
Ammonia	Environmental Protection Agency Method 350.1	L
Chlorides	Lachat I.C. Method 10-511-00-1A	L
Sulfate	Lachat I.C. Method 10-511-00-1A	L
Methane	RSKSOP-175 <sup>a/</sup> and RSKSOP-194	L
Total Organic Carbon	RSKSOP-102	L
BTEX, TMBs, and Total Fuel Carbon <sup>b/</sup>	RSKSOP-133	L

<sup>a/</sup> RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

<sup>b/</sup> BTEX = Benzene, toluene, ethylbenzene, and xylenes; TMB = trimethylbenzene.

**TABLE 1B**  
**SUMMARY OF GROUNDWATER ANALYTICAL METHODS**  
**FEBRUARY 1999**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Analyte	Method	Field (F) or Fixed-Base Laboratory (L)
Oxidation/Reduction Potential	Direct Reading Meter	F
Dissolved Oxygen	Direct Reading Meter	F
Conductivity	Direct Reading Meter	F
Temperature	Direct Reading Meter	F
pH	Direct Reading Meter	F
Ferrous Iron (Fe <sup>2+</sup> )	Colorimetric, Hach <sup>®</sup> Method 8146 or equivalent	F
Sulfide	Colorimetric, Hach <sup>®</sup> Method 8131 or equivalent	F
Carbon Dioxide	Titrimetric, Hach <sup>®</sup> Method 1436-01 or equivalent	F
Alkalinity (Carbonate [CO <sub>3</sub> <sup>2-</sup> ] and Bicarbonate [HCO <sub>3</sub> <sup>-</sup> ])	Titrimetric, Hach <sup>®</sup> Method 8221 or equivalent	F
Nitrate + Nitrite	Lachat FIA Method 10-107-04-2-A	L
Ammonia	Lachat FIA Method 10-107-06-1-A	L
Chlorides	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane and Ethene	RSKSOP-175 <sup>a/</sup> and RSKSOP-194	L
Total Organic Carbon	RSKSOP-102	L
BTEX, TMBs, and MTBE <sup>b/</sup>	RSKSOP-122	L

<sup>a/</sup> RSKSOP = Robert S. Kerr Laboratory (now known as NRMRL) standard operating procedure.

<sup>b/</sup> BTEX = Benzene, toluene, ethylbenzene, and xylenes; TMB = trimethylbenzene;  
MTBE = methyl-tertiary butyl ether.

**TABLE 2**  
**WELL POINT CONSTRUCTION SUMMARY**  
**FEBRUARY 1999**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Push ID	Depth (ft bgs) <sup>a/</sup>	Screened Interval		Annular Seal (ft bgs)	Remarks
		New (ft bgs)	Original (ft bgs)		
CPT 08SR	16.6	6.8-16.6	10.0-16.6	Came out with push rods 23.8-24.0 6.8-7.0 24.6-24.8 6.8-7.0 7.8-8.0	strong hydrocarbon odor
CPT 08DR	27.4	24.2-27.4	24.0-27.3		
CPT 15SR	17.0	7.2-17.0	14.6-17.9		strong hydrocarbon odor
CPT 19DR*	33.0	24.9-31.5	22.7-26.0		
CPT 1SR	17.0	7.2-17.0	13.7-17.0		placed through existing manhole access
CPT 11SR	18.0	8.2-18.0	15.5-18.8		hydrocarbon odor

\*The screen in CPT 19DR was originally set from about 27 to 33 feet, however the whole assembly moved up 1.5 feet as the rods were retracted. An electronic water level indicator was used to sound the bottom and it was determined that the well was intact.

<sup>a/</sup> ft bgs = feet below ground surface.

**TABLE 3**  
**SUMMARY OF WATER LEVEL ELEVATION DATA**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Measurement Location	Northing (ft) <sup>b/</sup>	Easting (ft)	Date (mo/yr) <sup>c/</sup>	Datum Elevation (ft amsl) <sup>d/</sup>	Total Depth (ft bgs) <sup>e/</sup>	LNAPL <sup>a/</sup> Observed (Yes/No)	Water Depth (ft)	Water Level Elevation (ft amsl)
<b>Monitoring Points</b>								
CPT-01S	413590	480024	Apr-94	26.48	17.00	No	9.22	17.26
CPT-01SR <sup>g/</sup>	413590	480024	Feb-99	NM <sup>h/</sup>	17.00	No	14.1	NA <sup>h/</sup>
CPT-02S	413721	480113	Apr-94	25.51	13.00	No	7.18	18.33
CPT-03S	413754	479968	Apr-94	25.64	13.00	No	8.04	17.60
CPT-04S	413863	479748	Apr-94	26.31	17.00	No	8.50	17.81
CPT-05S	NM	NM	Apr-94	NM	NA	No	NM	NM
CPT-06S	413657	480522	Apr-94	24.10	16.60	No	6.60	17.50
CPT-07S	415476	479293	Apr-94	25.85	15.00	No	6.92	18.93
CPT-07D	415475	479294	Apr-94	25.83	28.20	No	7.02	18.81
CPT-08P	NM	NM	Apr-94	NM	12.10	No	DRY	NA
CPT-08S	414102	479416	Apr-94	26.18	16.6	No	8.42	17.76
CPT-08D	NM	NM	Apr-94	NM	27.30	No	8.52	NA
CPT-09S	414644	479271	Apr-94	23.98	18.60	No	6.04	17.94
CPT-10S	414410	479107	Apr-94	NM	18.60	No	7.85	NA
CPT-11P	NM	NM	Apr-94	NM	13.00	No	6.15	NA
CPT-11S	NM	NM	Apr-94	NM	18.80	No	8.70	NA
CPT-11SR	NM	NM	Feb-99	NM	18.80	No	13.4	NA
CPT-12P	NM	NM	Apr-94	NM	5.10	No	DRY	NA
CPT-12S	413955	479095	Apr-94	26.24	17.80	No	8.76	17.48
CPT-12D	413955	479103	Apr-94	26.23	23.40	No	8.83	17.40
CPT-13S	414106	479154	Apr-94	27.03	17.30	No	9.18	17.85
CPT-14S	413951	479626	Apr-94	NM	17.60	No	NM	NM
	413951	479626	Feb-99	NM	17.60	No	DRY	NA
CPT-14D	NM	NM	Feb-99	NM	NM	No	15.5	NA
CPT-15S	414104	479746	Apr-94	25.44	17.90	Yes <sup>j/</sup>	8.45	16.99
CPT-15SR	414104	479746	Feb-99	NM	17.90	Yes	13.2	NA
CPT-16S	414307	479748	Apr-94	NM	13.40	No	5.65	NA
CPT-16D	414307	479748	Apr-94	NM	24.10	No	6.06	NA
	414307	479748	Sep-97	NM	24.10	No	NM	NM
	414307	479748	Feb-99	NM	24.10	No	12.2	NA
CPT-17S	413912	479430	Apr-94	26.98	18.80	No	9.35	17.63
CPT-18S	413813	479294	Apr-94	26.11	18.70	Yes <sup>j/</sup>	12.10	14.01
CPT-19P	413733	479484	Apr-94	NA	10.10	No	NM	NM
CPT-19S	413733	479484	Apr-94	NM	15.90	No	8.96	NA
CPT-19D	413733	479484	Apr-94	NM	26.00	No	8.85	NA
CPT-19DR	413733	479484	Feb-99	NM	26.00	No	15.4	NA

**TABLE 3 (Continued)**  
**SUMMARY OF WATER LEVEL ELEVATION DATA**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Measurement Location	Northing (ft) <sup>b/</sup>	Easting (ft)	Date (mo/yr) <sup>c/</sup>	Datum Elevation (ft amsl) <sup>d/</sup>	Total Depth (ft bgs) <sup>e/</sup>	LNAPL <sup>a/</sup> Observed (Yes/No)	Water Depth (ft)	Water Level Elevation (ft amsl)
CPT-20S	413842	479557	Apr-94	26.74	15.40	No	9.13	17.61
CPT-21S	414447	480032	Apr-94	24.42	14.90	No	4.36	20.06
CPT-22S	414388	480694	Apr-94	25.92	17.90	No	6.31	19.61
CPT-22D	414388	480694	Apr-94	NM	30.40	No	9.33	NA
CPT-23S	NM	NM	Apr-94	NM	NA	No	NM	NM
CPT-24S	NM	NM	Apr-94	NM	15.60	No	DRY	NA
CPT-25S	414674	480669	Apr-94	26.59	20.90	No	9.00	17.59
CPT-26S	414382	481072	Apr-94	24.88	23.20	No	9.16	15.72
CPT-27S	413518	478754	Apr-94	26.04	17.40	No	9.83	16.21
CPT-27D	413518	478754	Apr-94	NM	28.40	No	NM	NM
CPT-28S	413685	478465	Apr-94	27.47	20.40	No	11.08	16.39
	413685	478465	Feb-99	27.47	20.40	No	16.1	11.37
CPT-29S	NM	NM	Apr-94	NM	16.30	No	NM	NM
75S	413225	478969	Apr-94	27.18	27.66	No	10.27	16.91
75D	413236	478978	Apr-94	27.10	35.86	No	10.41	16.69
76S	412555	479452	Apr-94	30.90	29.60	No	14.58	16.32
76D	412549	479447	Apr-94	30.88	37.42	No	14.56	16.32
77S	412880	479886	Apr-94	23.97	18.23	No	NM	NM
77D	412889	479894	Apr-94	23.49	22.64	No	NM	NM
78S	412821	478908	Apr-94	29.66	30.68	No	13.22	16.44
78D	412827	478900	Apr-94	29.95	37.71	No	13.52	16.43
DM 204S	415508	480856	Apr-94	24.91	16.00	No	6.87	18.04
DM 204D	415504	480861	Apr-94	24.76	34.00	No	6.73	18.03
DM 336S	412263	479909	Apr-94	24.37	16.00	No	7.93	16.44
DM 336D	412262	479912	Apr-94	24.38	36.00	No	8.53	15.85
DM 338S	412932	479324	Apr-94	28.68	20.00	No	NM	NM
DM 338D	412935	479321	Apr-94	28.83	39.00	No	NM	NM
DM 339S	412894	480158	Apr-94	24.81	14.50	No	NM	NM
DM 339D	412891	480157	Apr-94	24.74	28.00	No	NM	NM
DM 340S	413925	480765	Apr-94	22.16	18.50	No	4.79	17.37
DM 341S	413750	480309	Apr-94	25.42	19.00	No	NM	NM
DM 341D	413755	480303	Apr-94	25.60	28.00	No	NM	NM
DM 342S	414840	479750	Apr-94	24.94	19.00	No	4.61	20.33
	414840	479750	Feb-99	24.94	19.00	No	11.7	13.24
DM 342D	414838	479748	Apr-94	25.09	28.00	No	4.72	20.37
	414838	479748	Sep-97	25.09	28.00	No	8.62	16.47
	414838	479748	Feb-99	25.09	28.00	No	11.5	13.59

**TABLE 3 (Concluded)**  
**SUMMARY OF WATER LEVEL ELEVATION DATA**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Measurement Location	Northing (ft) <sup>b/</sup>	Easting (ft)	Date (mo/yr) <sup>c/</sup>	Datum Elevation (ft amsl) <sup>d/</sup>	Total Depth (ft bgs) <sup>e/</sup>	LNAPL <sup>a/</sup> Observed (Yes/No)	Water Depth (ft)	Water Level Elevation (ft amsl)
DM 343S	413597	479448	Apr-94	26.62	18.00	No	8.65	17.97
	413597	479448	Sep-97	26.62	18.00	No	11.82	14.80
	413597	479448	Feb-99	26.62	18.00	No	14.9	11.72
DM 343D	413603	479439	Apr-94	26.62	30.00	No	8.60	18.02
	413603	479439	Sep-97	26.62	30.00	No	11.80	14.82
	413603	479439	Feb-99	26.62	30.00	No	14.9	11.72
DM 344S	414415	480259	Apr-94	23.44	18.00	Yes	9.67	13.77
	414415	480259	Sep-97	23.44	18.00	Yes	NM	NM
	414415	480259	Feb-99	23.44	18.00	Yes	13.5	9.94
DM 344D	414408	480263	Apr-94	23.49	30.00	No	4.36	19.13
	414408	480263	Sep-97	23.49	30.00	No	7.57	15.92
	414408	480263	Feb-99	23.49	30.00	No	10.0	13.49
DM 345S	414255	479634	Apr-94	25.60	19.00	No	6.32	19.28
	414255	479634	Feb-99	25.60	19.00	No	FLOODED	NA
DM 346S	414670	478942	Apr-94	29.62	22.00	No	10.34	19.28
DM 346D	414674	478945	Apr-94	29.56	45.00	No	10.28	19.28
DM 347S	NA	NA	Apr-94	NM	NA	No	9.48	NA
DM 347D	NA	NA	Apr-94	NM	NA	No	9.50	NA
DM 348S	414290	478418	Apr-94	29.27	20.00	No	10.02	19.25
DM 348D	414295	478421	Apr-94	29.13	34.00	No	11.26	17.87
DM 349S	413817	478125	Apr-94	32.43	28.00	No	19.75	12.68
DM 349D	413821	478130	Apr-94	32.00	35.00	No	19.34	12.66
DM-383S	NM	NM	Feb-99	NM	NM	No	16.5	NA

<sup>a/</sup> LNAPL = Light non-aqueous phase liquid.

<sup>b/</sup> ft = Feet.

<sup>c/</sup> mo/yr = Month and year.

<sup>d/</sup> ft amsl = Feet above mean sea level.

<sup>e/</sup> ft bgs = Feet below ground surface.

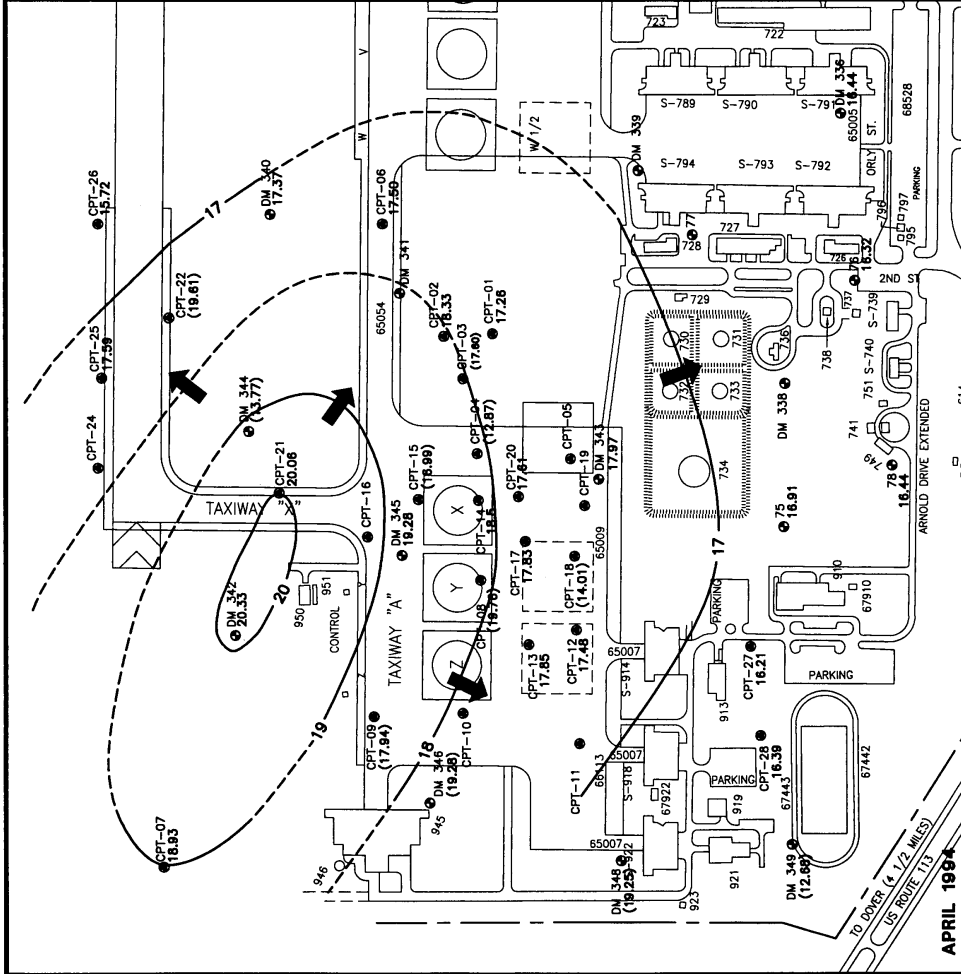
<sup>f/</sup> R = Replacement monitoring point.

<sup>g/</sup> NM = Not measured.

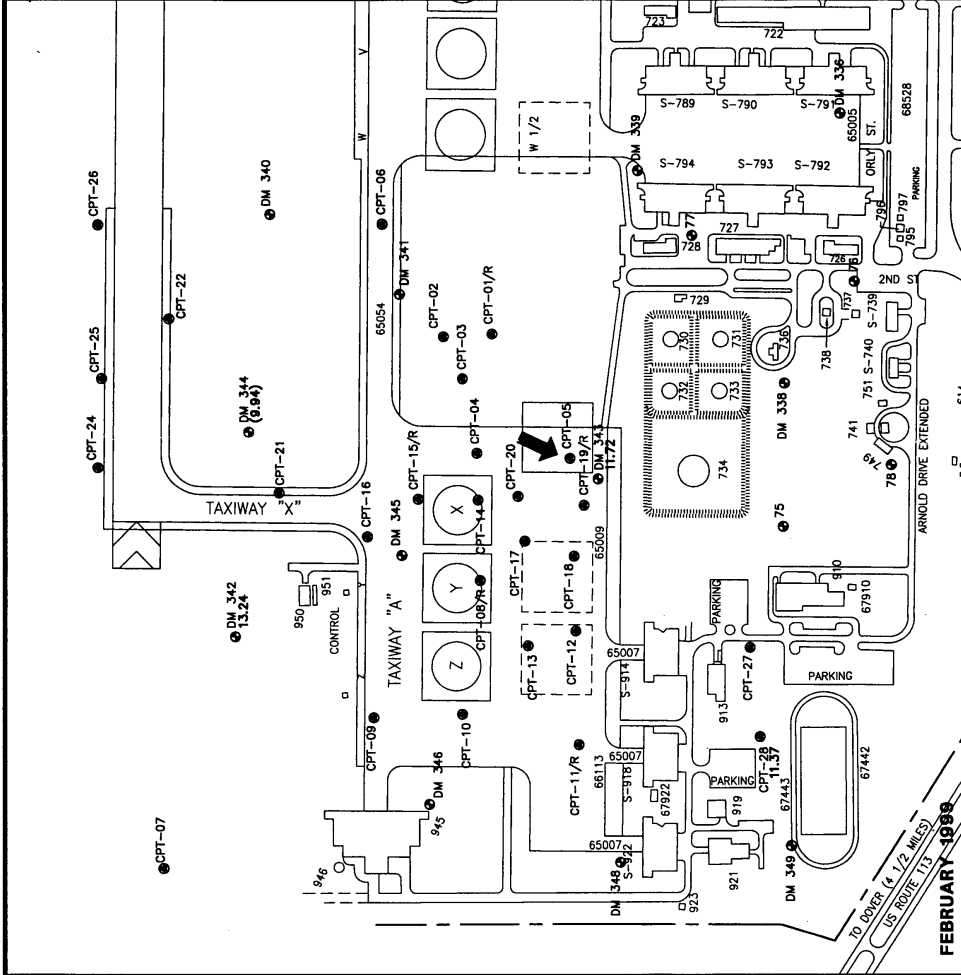
<sup>h/</sup> NA = Not available.

<sup>i/</sup> Emulsification was observed in monitoring point during sampling.





- LEGEND**
- DM 341 ● MONITORING WELL
  - CPT-01 ● MONITORING POINT AND CPT TEST LOCATION INSTALLED BY CPT RIG.
  - /R INDICATES REPLACEMENT WELL INSTALLED IN 1999
  - FORMER C-10 FUELING PAD
  - 20— WATER TABLE SURFACE CONTOUR (FEET ABOVE MEAN SEA LEVEL), DASHED WHERE INFERRED
  - 12.68 WATER TABLE SURFACE ELEVATION (FEET ABOVE MEAN SEA LEVEL)
  - (12.66) DATA NOT USED TO DEVELOP CONTOURS
  - ➔ APPROXIMATE GROUNDWATER FLOW DIRECTION

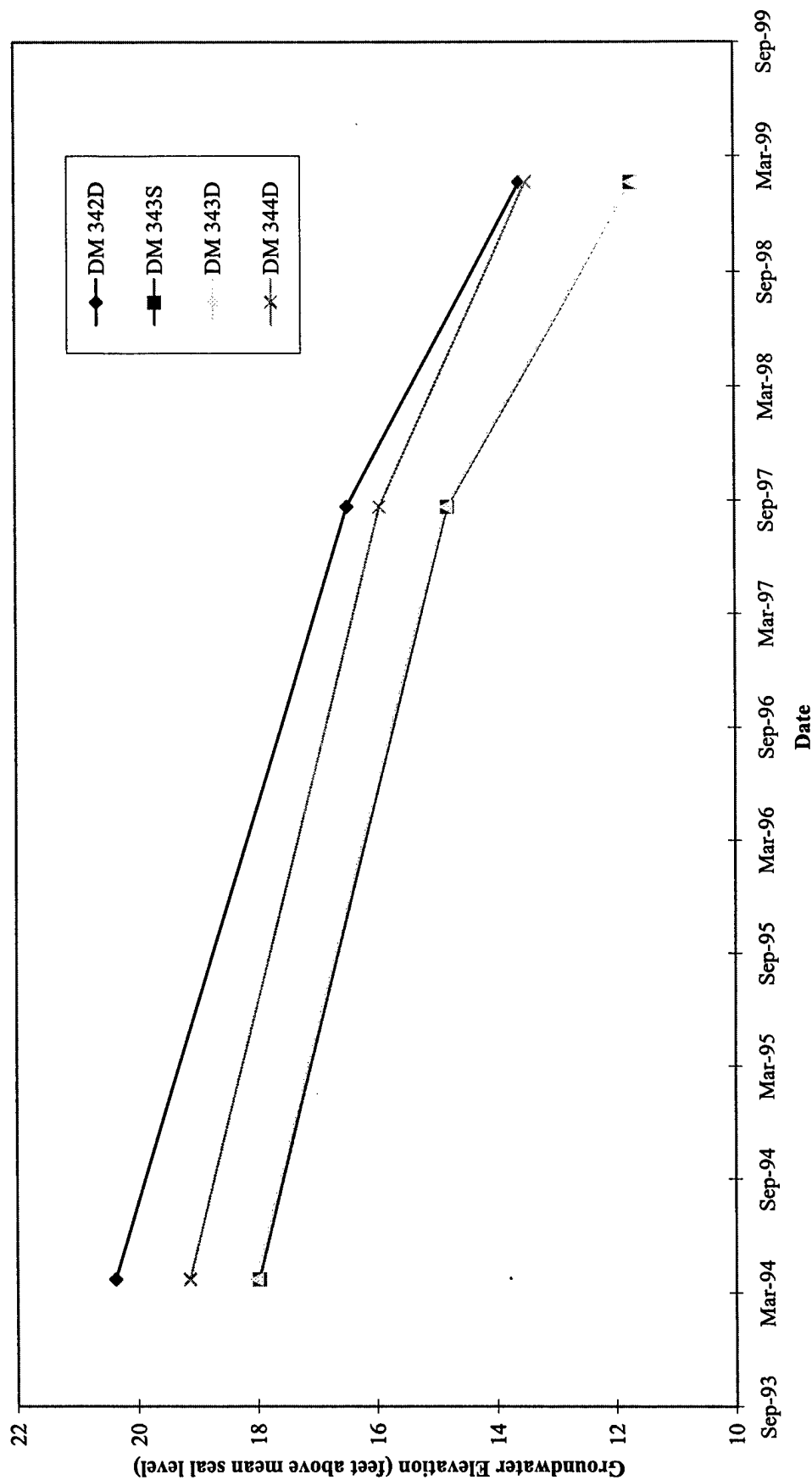


**FIGURE 2**  
**POTENTIOMETRIC**  
**SURFACE MAPS**  
**FOR SHALLOW WELLS**  
**(1994 AND 1999)**

Site SS27/XYZ  
 Intrinsic Remediation EE/CA Addendum  
 Dover AFB, Delaware

**PARSONS**  
 ENGINEERING SCIENCE, INC.  
 Denver, Colorado

**FIGURE 3**  
**GROUNDWATER ELEVATION VERSUS TIME FOR SELECTED WELLS**  
 SITE SS27/XYZ  
 INTRINSIC REMEDIATION EE/CA ADDENDUM  
 DOVER AFB, DELAWARE



significant decrease, the limited data for February 1999 is consistent with groundwater flow towards the southwest. An average hydraulic conductivity of 60.5 feet per day (ft/day) and an effective porosity of 0.3 were used to calculate an average groundwater advective velocity for the site in the EE/CA. Given an average hydraulic gradient of 0.002 ft/ft in 1994, an average advective groundwater velocity of 155 feet per year (ft/yr) is calculated from the source area to the southwest.

Vertical gradients also were calculated for the site in 1994. A downward vertical gradient existed across most of the site, ranging from 0.009 ft/ft at CPT-07 to 0.014 ft/ft at CPT-12. However, no downward vertical gradients were evident in 1999. Instead, an upward vertical gradient was calculated for the site in 1999. These upward gradients ranged from 0.0 ft/ft at DM343 to 0.3 ft/ft at DM344. The shift from a predominately downward vertical gradient to an upward vertical gradient is likely related to the decrease in shallow water table elevations.

## **2.2 LNAPL**

LNAPL was observed at monitoring well/point locations DM344S, CPT-15S, and CPT-18 in April 1994 (Table 3). A mobile LNAPL recovery and remediation pilot study using bioslurping was conducted in 1995, and a product skimmer installed in well DM344S. LNAPL was subsequently observed at well/points CPT-15SR (1999) and DM344S (1997 and 1999). To date, a full scale bioslurping system has not been installed. Therefore, areas of free product and/or residual LNAPL soil contamination remain at the site, and act as a continuing source for groundwater contamination.

## **2.3 Total BTEX in Groundwater**

BTEX compounds were detected in groundwater samples collected from 4 of the 14 monitoring wells/points included in the September 1997 sampling event, and in groundwater samples collected from 5 of the 12 monitoring wells/points included in the February 1999 sampling event. BTEX concentrations in groundwater are summarized for the period from April 1994 to February 1999 in Table 4. In order to evaluate trends in BTEX concentrations and distribution through time, the areal distributions of total BTEX in groundwater for April 1994, September 1997, and February 1999 are presented on Figure 4. For all clustered well/point locations, the sample from the well/point with the highest BTEX concentration is shown and used to contour BTEX isopleths.

Results of the September 1997 and February 1999 sampling events indicate that the BTEX plume has decreased in concentration, and the extent of the BTEX plume has stabilized. The BTEX plume has stabilized along a northeast to southwest trend and is approximately 1,200 feet wide and 2,400 feet long based on the 10 micrograms per liter ( $\mu\text{g/L}$ ) contour inferred from 1999 sampling data.

Total BTEX concentrations ranged up to 411,000E  $\mu\text{g/L}$  (extrapolated value) for well location DM344S and 11,300,000E  $\mu\text{g/L}$  for well location CPT-15S for the April 1994 sampling event. Emulsified LNAPL was observed in the samples from these locations in 1994, and the high BTEX concentrations are indicative of the LNAPL in

**TABLE 4**  
**SUMMARY OF FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Sample Location	Sampling Date	Benzene (µg/L) <sup>e/</sup>	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX <sup>d/</sup> (µg/L)	Trimethylbenzenes (µg/L)	TVH <sup>b/</sup> (mg/L) <sup>f/</sup>	TEH <sup>c/</sup> (mg/L)	Fuel Carbon (mg/L)	MTBE <sup>d/</sup> (mg/L)
<b>Groundwater Monitoring Points</b>											
CPT-1SR	Feb-99	BLQ <sup>g/</sup>	BLQ	BLQ	BLQ	ND <sup>h/</sup>	ND	NS <sup>j/</sup>	NS	NS	ND
CPT-02S	Apr-94	0.4J <sup>j/</sup>	2.3J	ND	1.2J	3.9	ND	0.2	ND	NS	NS
CPT-06S	Apr-94	ND	7.4	ND	1.3J	8.7	ND	0.2	ND	NS	NS
CPT-07S	Apr-94	ND	1.5	0.4J	1.9J	17	ND	0.2	ND	NS	NS
	Sep-97	ND	ND	ND	ND	ND	ND	NS	NS	ND	NS
CPT-08S	Apr-94	0.9J	7.4	0.4J	1.5J	10	0.9J	0.2	0.7	NS	NS
CPT-08D	Apr-94	7.7	19	2.6J	7.5	37	7.6J	0.4	ND	NS	NS
CPT-09S	Apr-94	2.2J	2.6J	ND	1.7J	6.5	0.6J	0.2	ND	NS	NS
	Sep-97	BLQ	ND	BLQ	ND	ND	BLQ	NS	NS	BLQ	NS
CPT-10S	Apr-94	ND	3.9J	ND	0.8J	4.7	ND	ND	ND	NS	NS
Duplicate	Apr-94	0.9J	6.5	0.4J	1.3J	9.1	ND	0.2	0.7	NS	NS
CPT-11P	Apr-94	ND	6.5	ND	1.3J	7.8	ND	0.2	ND	NS	NS
CPT-11S	Apr-94	ND	8.8	0.5J	1.7J	11	ND	0.2	ND	NS	NS
CPT-11SR	Feb-99	ND	BLQ	ND	BLQ	ND	ND	NS	NS	NS	ND
CPT-12S	Apr-94	0.4J	3.7J	ND	1.0J	5.1	ND	0.2	ND	NS	NS
CPT-12D	Apr-94	1.7J	8.3	1.1J	3.6J	15	2.8J	ND	ND	NS	NS
CPT-13S	Apr-94	0.9J	5.6	0.8J	3.0J	10	ND	ND	ND	NS	NS
CPT-14S	Apr-94	920	430	210	790	2,350	455	14	5.9J	NS	NS
Duplicate	Apr-94	960	460	240	940	2,600	744	NS	NS	NS	NS
CPT-14D	Feb-99	12.6	21.7	4.9	21.1	60.3	10	13.3	NS	NS	185
CPT-15S	Apr-94	970,000E <sup>k/</sup>	2,500,000E	1,600,000E	6,200,000E	11,300,000	11,600,000E	NS	NS	NS	NS
CPT-16S	Apr-94	14	34	54	55	157	180	1.1	2.5	NS	NS

**TABLE 4 (Continued)**  
**SUMMARY OF FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Sample Location	Sampling Date	Benzene (µg/L) <sup>e</sup>	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX <sup>d</sup> (µg/L)	Trimethyl- benzenes (µg/L)	TVH <sup>b</sup> (mg/L) <sup>g</sup>	TEH <sup>d</sup> (mg/L)	Fuel	
										Carbon (mg/L)	MTBE <sup>d</sup> (mg/L)
CPT-16D	Apr-94	350E	64	28	38	480	61	NS	NS	NS	NS
	Sep-97	394	2.1	36.2	4.6	437	2	NS	NS	1160	NS
Duplicate	Sep-97	403	2.2	37.2	4.7	447	2	NS	NS	1190	NS
	Feb-99	587	4.3	232	10.6	834	19.1	NS	NS	NS	3.1
CPT-18S	Apr-94	6,500	13,000	820	2,600	23,000	980	NS	NS	NS	NS
CPT-19S	Apr-94	ND	ND	ND	1.4J	1.4	2.3	ND	ND	NS	NS
CPT-19D	Apr-94	22	49	12	53	136	22	0.4	ND	NS	NS
CPT-19DR	Feb-99	34.8	12.6	4.4	18.8	70.6	9.1	NS	NS	NS	333
CPT-21S	Apr-94	55	150	30	143	378	32	1.4	0.8	NS	NS
CPT-22S	Apr-94	6.7	45	7	48	107	26	0.5	ND	NS	NS
CPT-22D	Apr-94	1.1J	14	0.7J	3.0J	19	2.8J	NS	NS	NS	NS
CPT-25S	Apr-94	1.2J	13	2.1J	8.9	25	8.1	ND	ND	NS	NS
CPT-26S	Apr-94	0.9J	6.1	1.5J	6.6J	15	6.5	NS	NS	NS	NS
	Sep-97	BLQ	ND	ND	ND	ND	1.9	NS	NS	34.3	NS
CPT-27S	Apr-94	0.7J	6	1.5J	6.3	15	6.9J	0.2	ND	NS	NS
	Sep-97	ND	ND	ND	ND	ND	ND	NS	NS	ND	NS
CPT-27D	Apr-94	5.4	18	1.7J	6.2J	31	2.0J	NS	NS	NS	NS
	Sep-97	ND	ND	ND	ND	ND	ND	NS	NS	ND	NS
CPT-28S	Apr-94	5	54	5	25	89	8.7J	NS	NS	NS	NS
	Feb-99	BLQ	BLQ	ND	ND	ND	ND	NS	NS	NS	1.1
CPT-29S	Apr-94	ND	22	0.5J	2.2J	25	1.8J	NS	NS	NS	NS
Duplicate	Apr-94	ND	21	0.6J	2.6J	24	2.0J	NS	NS	NS	NS
DM 341S	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS

**TABLE 4 (Continued)**  
**SUMMARY OF FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER**  
**SITE SS27/KYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Sample Location	Sampling Date	Benzene (µg/L) <sup>e</sup>	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX <sup>d</sup> (µg/L)	Trimethyl- benzenes (µg/L)	TVH <sup>b</sup> (mg/L) <sup>g</sup>	TEH <sup>c</sup> (mg/L)	Fuel	
										Carbon (mg/L)	MTBE <sup>d</sup> (mg/L)
Groundwater Monitoring Wells											
DM 341D	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
DM 341DD	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
DM 342S	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Sep-97	ND	ND	ND	BLQ	ND	ND	NS	NS	BLQ	NS
	Feb-99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DM342D	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Sep-97	ND	BLQ	ND	BLQ	ND	ND	NS	NS	BLQ	NS
	Feb-99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DM343S	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Sep-97	ND	ND	ND	ND	ND	1.5	NS	NS	41.1	NS
	Feb-99	BLQ	BLQ	BLQ	BLQ	ND	BLQ	NS	NS	NS	35.9
	Feb-99	ND	BLQ	BLQ	BLQ	ND	BLQ	NS	NS	NS	34.1
Duplicate DM343D	Mar-94	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Sep-97	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
	Feb-99	ND	BLQ	ND	BLQ	ND	ND	NS	NS	NS	15.3
DM344S	Mar-94	26,000E	49,000E	66,000E	270,000E	411,000E	1,900,000E	NS	NS	NS	NS
	Sep-97	5,930	1,910	1,030	3,390	12,300	1,440	NS	NS	18,300	NS
	Feb-99	2,010	198	447	2,640	5,300	1,340	NS	NS	NS	22.7
DM344D	Mar-94	560	ND	82	5J	647J	NS	NS	NS	NS	NS
	Sep-97	1.6	BLQ	BLQ	BLQ	1.6	BLQ	NS	NS	15.6	NS
	Feb-99	7.6	BLQ	2.8	BLQ	10.4	2.1	NS	NS	NS	7.5
DM345S	Mar-94	ND	ND	16	13	29	NS	NS	NS	NS	NS
Duplicate	Mar-94	ND	ND	16	14	30	NS	NS	NS	NS	NS

**TABLE 4 (Concluded)**  
**SUMMARY OF FUEL HYDROCARBON COMPOUNDS DETECTED IN GROUNDWATER**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Sample Location	Sampling Date	Benzene (µg/L) <sup>e/</sup>	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	Total BTEX <sup>d/</sup> (µg/L)	Total Trimethyl-benzenes (µg/L)	TVH <sup>b/</sup> (mg/L) <sup>g/</sup>	TEH <sup>d/</sup> (mg/L)	Fuel Carbon (mg/L)	MTBE <sup>d/</sup> (mg/L)
DM-349S	Sep-97	0.9	BLQ	ND	BLQ	0.9	1.8	NS	NS	11.8	NS
Duplicate	Sep-97	BLQ	ND	ND	ND	ND	1.8	NS	NS	38.9	NS
DM-349D	Sep-97	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS

<sup>a/</sup> BTEX = Benzene, Toluene, Ethylbenzene, and Total Xylenes.

<sup>b/</sup> TVH = Total Volatile Hydrocarbons.

<sup>c/</sup> TEH = Total Extractable Hydrocarbons.

<sup>d/</sup> MTBE = Methyl tertiary-butyl ether.

<sup>e/</sup> µg/L = micrograms per liter.

<sup>g/</sup> mg/L = milligrams per liter.

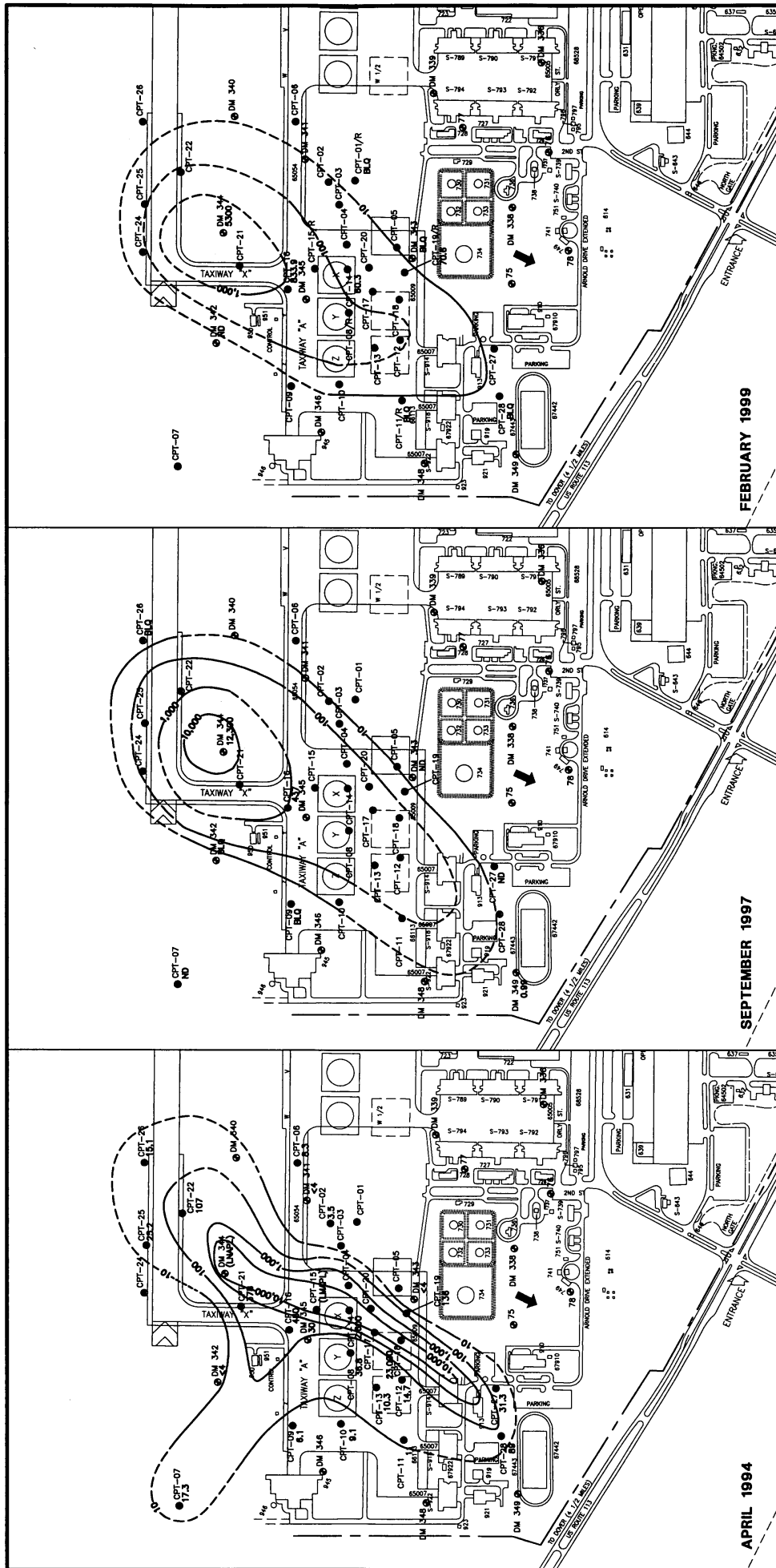
<sup>h/</sup> BLQ = Below Limit of Quantitation.

<sup>i/</sup> ND = Not detected above the reported quantification limit.

<sup>j/</sup> NS = Not sampled.

<sup>k/</sup> J = Indicates an estimated value when the compound is detected, but is below the Practical Quantitation Limit.

<sup>l/</sup> E = Extrapolated value.



**FIGURE 4**

**TOTAL BTEX ISOPLETH MAPS**

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

**PARSONS**  
PARSONS ENGINEERING SCIENCE, INC.  
Denver, Colorado



**LEGEND**

DM 341 ● MONITORING WELL

CPT-01 ● MONITORING POINT AND CPT TEST LOCATION INSTALLED BY CPT RIG.

/R INDICATES REPLACEMENT WELL INSTALLED IN 1999

◻ FORMER C-10 FUELING PAD

➔ APPROXIMATE GROUNDWATER FLOW DIRECTION

—10— TOTAL BTEX CONCENTRATION IN MICROGRAMS PER LITER (µg/L)

89 TOTAL BENZENE, TOLUENE, ETHYLBENZENE AND XYLENES (BTX) CONCENTRATIONS (µg/L)

ND NOT DETECTED

BLQ BELOW LIMIT OF QUANTITATION

(LNAPL) LNAPL EMULSIFIED IN SAMPLE



the sample. In September 1997, total BTEX concentrations ranged up to 12,300  $\mu\text{g/L}$  at the source area (well DM344S), a concentration representative of dissolved BTEX in groundwater. The maximum BTEX concentration further decreased to 5,300  $\mu\text{g/L}$  (well location DM344S) for the February 1999 sampling event.

Figure 5 shows the total BTEX concentrations versus time for select wells/points along the plume axis. Shallow well/point locations CPT-11S, CPT-28S, and DM344S have all shown a decrease in BTEX concentration from April 1994 to February 1999. Wells/points screened in lower aquifer depths also experienced a decrease in BTEX concentration (CPT-19D and DM344D) from April 1994 to February 1999, with the exception of CPT-16D. Located beneath the LNAPL source area, the increase in BTEX concentration at CPT-16D is likely a result of downward migration of BTEX contaminants.

The observed BTEX plume stability is in contrast to an expanding plume as predicted by Bioplume II modeling presented in the EE/CA. The observed plume has not expanded as predicted by all of the Bioplume II models constructed for the EE/CA. The plume has stabilized, rather than migrating an additional 950 feet downgradient as predicted for a five-year simulation with no source removal. The difference between predicted and observed plume behavior may be attributed to a lower hydraulic gradient and groundwater velocity than previously estimated at the site; LNAPL sorbing to soil particles in the vadose zone due to a drop of the water table across the site; less groundwater volume in contact with residual LNAPL contamination due to the water table drop; and/or a more rapid rate of biodegradation than previously calculated.

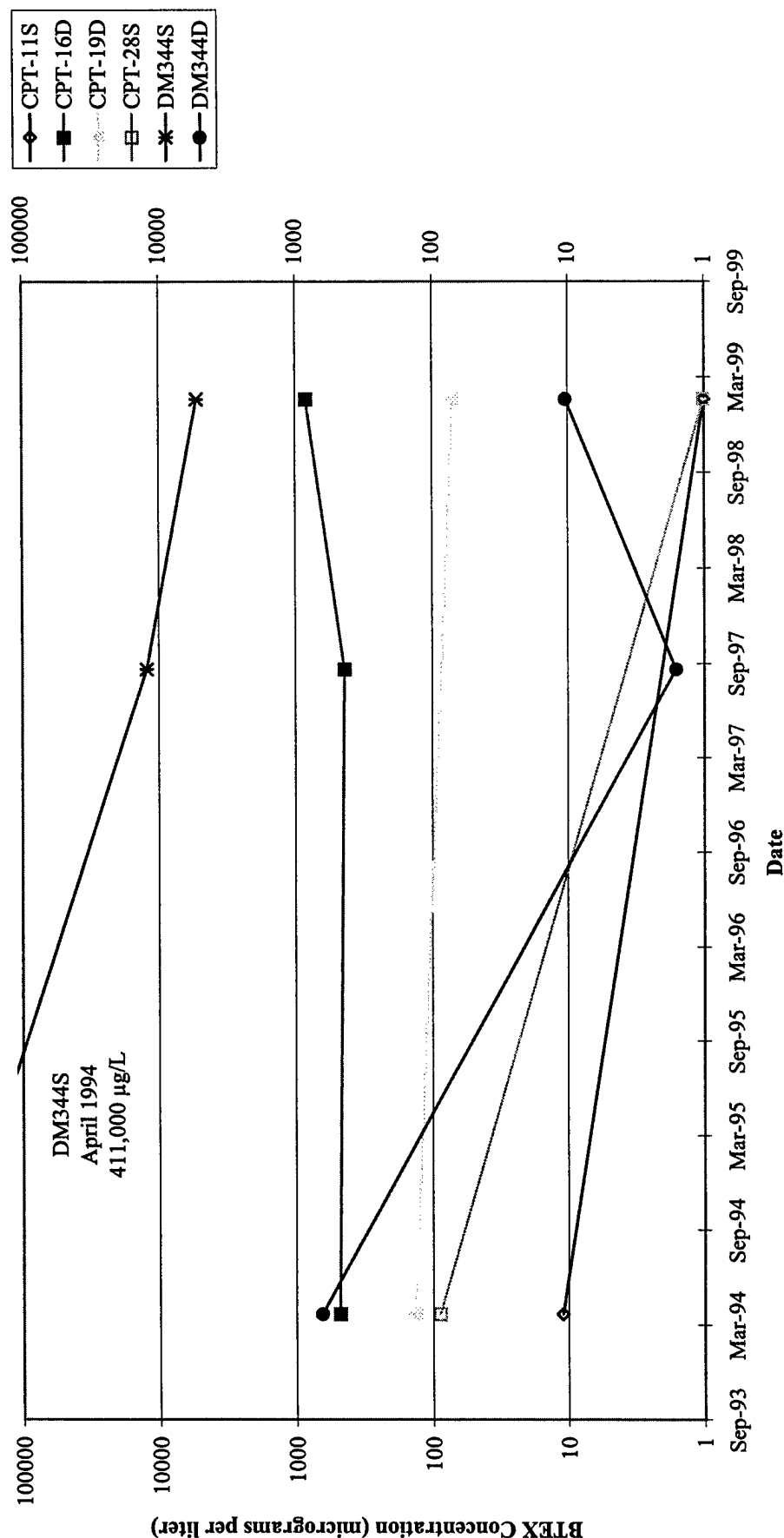
#### 2.4 Inorganic Chemistry and Geochemical Indicators of Biodegradation

As discussed in the EE/CA, microorganisms obtain energy for cell production and maintenance by facilitating thermodynamically advantageous oxidation/reduction (redox) reactions involving the transfer of electrons from electron donors to available electron acceptors. This results in the oxidation of the electron donor and the reduction of the electron acceptor. Electron donors at Site SS27/XYZ are natural organic carbon and fuel hydrocarbon compounds. Fuel hydrocarbons are completely degraded or detoxified if they are utilized as the primary electron donor for microbial metabolism (Bouwer, 1992).

Electron acceptors are elements or compounds that occur in relatively oxidized states and include DO, nitrate, manganese, ferric iron, sulfate, and carbon dioxide. Microorganisms preferentially utilize electron acceptors while metabolizing fuel hydrocarbons (Bouwer, 1992). DO is utilized first as the prime electron acceptor. After the DO is consumed, anaerobic microorganisms use electron acceptors in the following order of preference: nitrate, ferric iron, sulfate, and carbon dioxide. Anaerobic destruction of the BTEX compounds is associated with the accumulation of fatty acids, production of methane, solubilization of iron (ferrous iron), and reduction of nitrate and sulfate (Cozzarelli *et al.*, 1990; Wilson *et al.*, 1990).

It was suggested in the EE/CA that biodegradation of fuel hydrocarbons is occurring at the site via aerobic respiration and the anaerobic processes of iron reduction, sulfate

**FIGURE 5**  
**TOTAL BTX CONCENTRATION**  
**APRIL 1994 TO FEBRUARY 1999**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**



reduction, methanogenesis, and, to a lesser extent, denitrification. Areas of the site which show the greatest variation in concentrations of geochemical parameters relative to background conditions generally correspond well with areas of relatively low redox potential and high BTEX concentration. Geochemical parameters for site groundwater observed for September 1997 and February 1999 are discussed below. Table 5 summarizes the geochemical parameters analyzed during the April 1994, September 1997, and February 1999 sampling events.

#### **2.4.1 Oxidation/Reduction Potential**

ORP is a measure of the relative tendency of a solution to accept or transfer electrons. ORP was measured at 8 of 12 wells sampled during February 1999. The dominant electron acceptor being reduced by microbes during BTEX oxidation is related to the ORP of the groundwater. ORP data for the site are summarized in Table 5. Concentration isopleth maps of ORP measured at the site in April 1994, September 1997, and February 1999 are presented on Figure 6.

Comparison of Figures 4 and 6 indicates that areas with low ORP coincide with areas characterized by high dissolved BTEX concentrations. Comparison of ORP values measured in April 1994, September 1997, and February 1999 (Figure 6 and Table 5) suggest that the ORP of the groundwater at the site may be increasing (i.e., the lower limit of redox potential is increasing). ORP values ranged between -431 millivolts (mV) to 380 mV in April 1994, from -133 mV to 275 mV in September 1997, and from 11 mV to 147 mV in February 1999.

Results of the February 1999 sampling event may indicate a more oxidizing groundwater environment across the site. In particular, ORP measurements at CPT-16D, centrally located within the BTEX plume, increased from -431 mV in 1994 to -35 mV in September 1997, and to 147 mV in 1999. While the measurement of ORP is sensitive to methods of field measurement and sampling techniques, an increase in ORP could be related to lower groundwater levels (see earlier discussion of potential concentration-reducing effects) or to a decrease in microbial activity due to decreasing BTEX concentrations.

These data suggest that dissolved BTEX at the site may be subjected to a variety of biodegradation processes, including aerobic respiration, denitrification, and iron reduction. However, many authors have noted that field ORP data alone cannot be used to reliably predict the electron acceptors that may be operating at a site, because the platinum electrode probes are not sensitive to some redox couples (e.g., sulfate/sulfide) (Stumm and Morgan, 1981; Godsey, 1994; Lovley *et al.*, 1994).

#### **2.4.2 Dissolved Oxygen**

DO concentrations were measured at 7 wells/points in September 1997, and at 12 wells/points in February 1999 (Table 5). DO concentration contour maps for the April 1994, September 1997, and February 1999 sampling events are presented in Figure 7. Comparison of Figure 4 with Figure 7 shows that elevated total BTEX concentrations correspond to areas characterized by reduced DO concentrations. The lowest DO

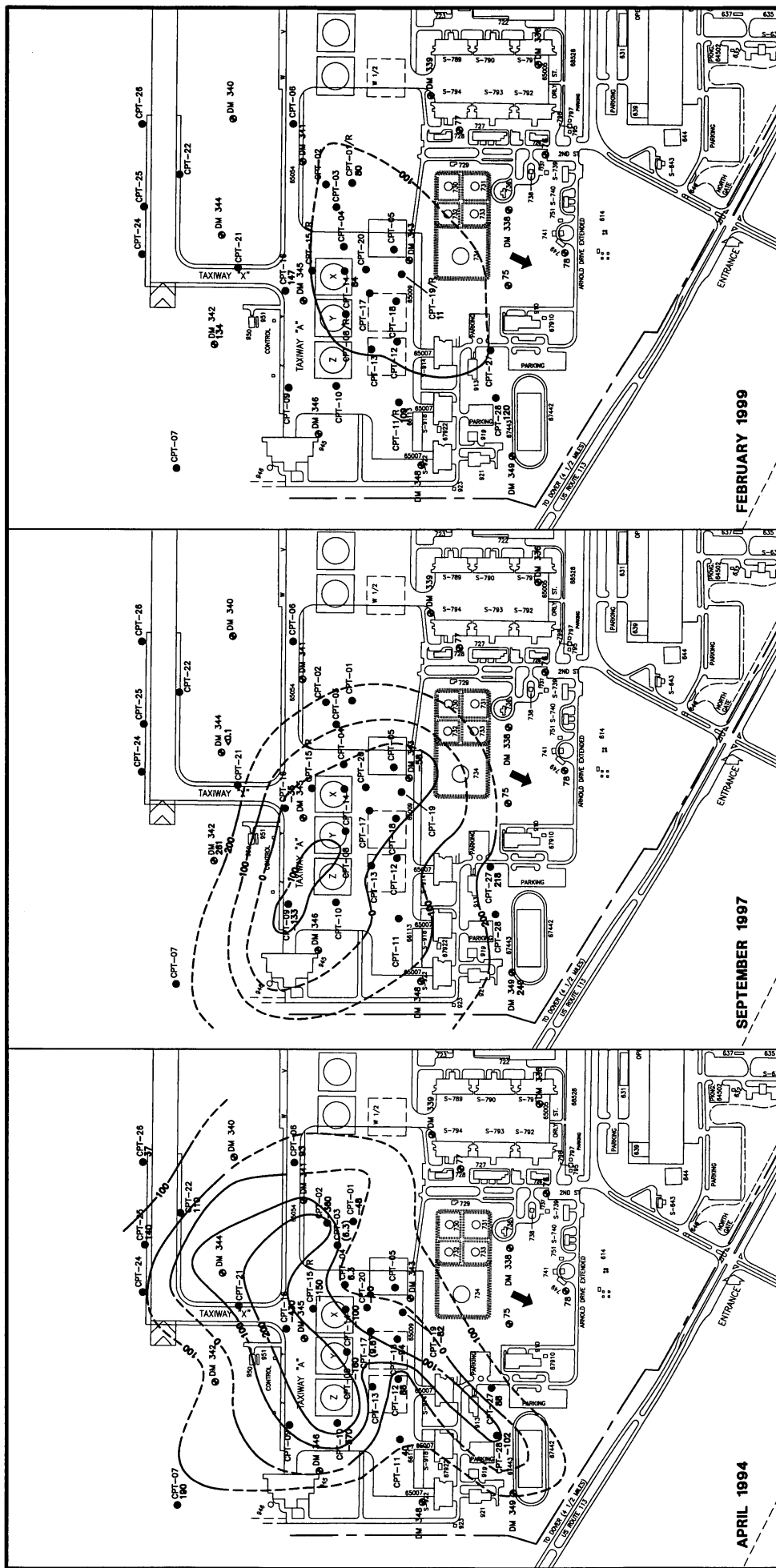
**TABLE 5**  
**SUMMARY OF GROUNDWATER GEOCHEMICAL DATA**  
**SITE SS27/XYZ**  
**INTRINSIC REMEDIATION EE/CA ADDENDUM**  
**DOVER AFB, DELAWARE**

Sample Location	Sampling Date	Water Temp. (°C) <sup>iv</sup>	pH (su) <sup>v</sup>	Conductivity µmhos/cm <sup>vi</sup>	Dissolved Oxygen (mg/L) <sup>v</sup>	Redox Potential (mV) <sup>v</sup>	Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Nitrite as N (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Ferrous Iron (mg/L)	Methane (mg/L)	Ethene (mg/L)	Ethane (mg/L)	Chloride (mg/L)	TOC <sup>vi</sup> (mg/L)
<b>Groundwater Monitoring Points</b>																				
CPT-01S	Apr-94	12.7	4.79	NA <sup>iv</sup>	0.4	-48	NS	NS	NS	NS <sup>vi</sup>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CPT-01SR	Feb-99	13.0	5.60	149	1.2	80	20	50	NS	NS	NS	<0.10 <sup>vi</sup>	31	<0.1	1.5	1.01	NS	ND	3.63	2.11
CPT-02S	Apr-94	NS	5.67	NA	0.1	-356	110	NS	NS	0.25	0.002	NS	29	0.072	0.65	R <sup>v</sup>	NS	NS	NS	NS
CPT-03S	Apr-94	13.1	5.84	NA	5.0	NA	NS	NS	NS	1.1	ND	NS	25	0.022	0.34	NS	NS	NS	NS	NS
CPT-04S	Apr-94	13.1	5.88	NA	0.3	6	NS	NS	NS	1.3	0.002	NS	25	0.027	1.7	NS	NS	NS	NS	NS
CPT-06S	Apr-94	14.0	6.01	NA	0.5	93	38	NS	NS	ND	ND	NS	60	0.006	1.7	R	NS	NS	NS	NS
CPT-07S	Apr-94	14.7	5.25	NA	4.9	191	22	NS	NS	2.7	0.001	NS	17	0.022	0.26	R	NS	NS	NS	NS
CPT-07D	Apr-94	14.8	5.30	NA	5.2	187	NS	NS	NS	ND	0.001	NS	28	0.049	0.10	NS	NS	NS	NS	NS
CPT-08S	Apr-94	15.8	5.37	NA	0.4	-161	37	NS	NS	0.20	0.006	NS	26	0.027	2.1	R	NS	NS	NS	NS
CPT-08D	Apr-94	16.2	4.86	NA	0.3	130	15	NS	NS	0.80	0.001	NS	51	0.026	1.8	R	NS	NS	NS	NS
CPT-09S	Apr-94	14.2	6.19	NA	0.7	NA	102	NS	NS	ND	ND	NS	40	0.017	1.7	R	NS	NS	NS	NS
CPT-10S	Sep-97	NA	6.34	755	NS	-133	397	NS	NS	NS	NS	1.2	9.7	0.30	16	8.3	NS	NS	4.4	4.4
CPT-11S	Apr-94	14.2	6.28	NA	0.5	-370	41	NS	NS	3.5	0.004	NS	23	0.016	1.6	R	NS	NS	NS	NS
CPT-11P	Apr-94	14.1	5.47	NA	6.1	149	9	NS	NS	10.6	0.048	NS	26	ND	1.7	R	NS	NS	NS	NS
CPT-11S	Apr-94	14.9	5.34	NA	0.4	39	12	NS	NS	18.4	0.014	NS	8.7	0.019	1.0	R	NS	NS	NS	NS
CPT-11SR	Feb-99	11.0	5.80	125	6.5	109	40	10	7.21	NS	NS	<0.10	12.5	<0.1	<0.1	ND	ND	ND	1.01	1.08
CPT-12S	Apr-94	14.7	4.93	NA	0.3	89	24	NS	NS	2.6	0.003	NS	4.0	0.035	1.5	R	NS	NS	NS	NS
CPT-12D	Apr-94	15.5	4.92	NA	0.4	130	13	NS	NS	0.15	0.001	NS	54	0.025	0.23	R	NS	NS	NS	NS
CPT-13S	Apr-94	15.5	5.26	NA	0.4	NA	22	NS	NS	1.1	ND	NS	30	0.040	1.3	R	NS	NS	NS	NS
CPT-14S	Apr-94	16.9	6.02	NA	0.6	-104	198	NS	NS	1.3	0.009	NS	9.6	0.041	1.5	R	NS	NS	NS	NS
CPT-14D	Feb-99	14.3	NS	NA	4.5	84	NS	NS	NS	NS	NS	NS	NS	<0.1	0.4	0.306	ND	ND	NS	NS
CPT-15S	Apr-94	14.0	5.81	NA	0.3	-153	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CPT-16S	Apr-94	17.0	5.72	NA	4.2	-120	122	NS	NS	1.7	0.006	NS	7.4	0.021	1.6	R	NS	NS	NS	NS
CPT-16D	Apr-94	16.5	6.08	NA	0.3	-431	195	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS
Sep-97	19.6	6.54	384	0.1	-35	213	NS	NS	ND	NS	NS	0.43	2.9	ND	20	14	NS	NS	4.1	4.5
Feb-99	15.1	6.40	325	0.4	147	200	100	100	<0.10	NS	NS	<0.10	1.92	0.1	40	20.3	ND	ND	1.12	4.32
CPT-17S	Apr-94	14.0	5.73	NA	0.3	10	NS	NS	NS	0.80	0.004	NS	49	0.19	1.5	NS	NS	NS	NS	NS
CPT-18S	Apr-94	14.0	6.38	NA	0.5	-94	155	NS	NS	0.30	ND	NS	4.9	ND	1.6	R	NS	NS	NS	NS
CPT-19S	Apr-94	13.7	5.96	NA	0.4	-82	163	NS	NS	0.55	0.003	NS	64	0.022	1.4	R	NS	NS	NS	NS
CPT-19D	Apr-94	15.5	4.95	NA	0.6	115	14	NS	NS	0.05	0.001	NS	27	0.010	0.09	R	NS	NS	NS	NS
CPT-19DR	Feb-99	13.6	6.30	362	1.2	11	120	50	<0.10	NS	NS	<0.10	20.2	<0.1	2.5	2.84	ND	ND	4.43	2.87
CPT-20S	Apr-94	12.1	5.70	NA	0.4	-90	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CPT-21S	Apr-94	NA	NA	NA	1.0	NA	23	NS	NS	1.1	0.001	NS	19	0.026	1.7	R	NS	NS	NS	NS
CPT-22S	Apr-94	13.1	7.31	NA	0.6	109	NS	NS	NS	1.1	0.004	NS	33	0.012	0.35	R	NS	NS	NS	NS
CPT-22D	Apr-94	15.0	6.15	NA	0.3	285	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS
CPT-23S	Apr-94	13.0	6.03	NA	0.5	137	NS	NS	NS	ND	0.005	NS	60	0.064	1.3	R	NS	NS	NS	NS
CPT-26S	Apr-94	13.5	6.23	NA	0.8	37	NS	NS	NS	0.05	ND	NS	19	0.061	1.4	R	NS	NS	NS	NS
CPT-27S	Apr-94	15.0	4.47	NA	2.2	185	5	NS	NS	0.05	0.014	NS	33	0.033	0.16	R	NS	NS	NS	NS
Sep-97	NA	5.13	195	NA	NA	275	<1	160	0.75	NS	NS	ND	36	0.006	0.12	0.006	NS	NS	28	0.63

**TABLE 5 (Concluded)**  
**SUMMARY OF GROUNDWATER GEOCHEMICAL DATA**  
 SITE SS27/XYZ  
 INTRINSIC REMEDIATION EE/CA ADDENDUM  
 DOVER AFB, DELAWARE

Sample Location	Sampling Date	Water		Conductivity (µmhos/cm) <sup>d</sup>	Dissolved Oxygen (mg/L) <sup>e</sup>	Redox Potential (mV) <sup>f</sup>	Total Alkalinity (mg/L)	Carbon Dioxide (mg/L)	Nitrate + Nitrite as N		Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Sulfate (mg/L)	Hydrogen Sulfide		Iron (mg/L)	Methane (mg/L)	Ethene (mg/L)	Ethane (mg/L)	Chloride (mg/L)	TOC <sup>g</sup> (mg/L)
		Temp. (°C) <sup>h</sup>	pH (su) <sup>i</sup>																			
CPT-27D	Apr-94	17.3	4.96	NA	0.6	88	9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS
	Sep-97	NA	5.33	148	NS	218	10	370	0.17	NS	NS	NS	NS	31	NS	NS	3.7	0.055	NS	NS	13	2.5
	Feb-99	15.1	5.70	101	0.2	-103	53	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS
CPT-28S	Apr-94	15.5	5.38	NA	1.9	380	NS	NS	NS	NS	NS	NS	NS	<0.10	18.2	<0.1	<0.1	0.029	ND	ND	3.43	1.42
	Sep-97	NA	5.38	NA	1.9	380	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS
	Feb-99	15.1	5.70	101	0.2	-103	53	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	R	NS	NS	NS	NS
<b>Monitoring Wells</b>																						
DM 204S	Apr-94	10.6	6.50	NA	2.0	229	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 204D	Apr-94	11.7	6.47	NA	0.3	-233	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 339S	Apr-94	14.3	5.67	NA	0.3	-209	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 339D	Apr-94	16.5	5.81	NA	0.2	-216	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 340S	Apr-94	10.1	4.80	NA	NA	352	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 341S	Apr-94	NA	5.54	NA	2.0	221	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 341D	Apr-94	NA	5.50	NA	3.3	238	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 342S	Apr-94	10.1	5.29	NA	NA	60	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sep-97	19.5	6.01	56	7.4	273	<1	36	2.77	NS	NS	NS	NS	NS	2.3	NS	0.06	ND	NS	NS	NS	4.4	ND
Feb-99	8.8	5.60	89	1.7	134	20	5	0.5	NS	NS	NS	NS	NS	<0.10	12.3	<0.1	<0.1	ND	ND	ND	1.17	0.97
DM 342D	Apr-94	11.7	5.72	NA	7.4	37	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sep-97	17.8	5.72	57	5.6	261	12	76	0.68	NS	NS	NS	NS	NS	14	NS	0.06	ND	NS	NS	NS	3.9	ND
Feb-99	13.0	5.70	62	3.2	139	20	5	0.27	NS	NS	NS	NS	NS	<0.10	11.4	<0.1	0.1	0.016	ND	ND	1.03	0.893
DM 343S	Apr-94	14.7	5.67	NA	0.2	166	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sep-97	19.8	5.75	313	0.2	-44	103	NS	NS	NS	NS	NS	NS	NS	53	0.1	26	1.7	NS	NS	NS	7.6	8.3
Feb-99	10.3	5.60	195	2.0	NA	40	170	<0.10	NS	NS	NS	NS	NS	61.2	0.1	30	0.523	ND	ND	ND	4.79	5.77
DM 343D	Apr-94	17.0	5.50	NA	0.3	120	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sep-97	19.2	5.53	259	0.2	107	45	NS	NS	NS	NS	NS	NS	NS	65	NS	23	0.21	NS	NS	NS	7.8	5.9
Feb-99	16.0	5.60	232	0.4	NA	20	120	<0.10	NS	NS	NS	NS	NS	68.1	0.1	35	0.131	ND	ND	ND	5.31	4.77
DM 344S	Sep-97	18.7	6.45	456	<0.1	-58	236	NS	NS	NS	NS	NS	NS	17	1.0	4.5	9.5	NS	NS	NS	5.6	8.0
Feb-99	12.3	6.40	439	0.2	NA	240	40	<0.10	NS	NS	NS	NS	NS	10	0.4	22	14.4	0.004	ND	ND	3.78	10.7
DM 344D	Sep-97	17.3	5.87	113	<0.1	129	32	164	0.6	NS	NS	NS	NS	24	NS	5.3	0.038	NS	NS	NS	4.1	2.0
Feb-99	12.0	6.20	235	0.6	NA	100	40	<0.10	NS	NS	NS	NS	NS	<0.10	14	0.1	4	2.29	ND	ND	1.38	2.8
DM 346S	Apr-94	13.5	5.47	NA	7.5	373	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 346D	Apr-94	15.8	6.18	NA	4.5	359	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 348S	Apr-94	9.9	5.99	NA	8.3	235	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 348D	Apr-94	13.1	5.60	NA	4.8	275	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DM 349S	Sep-97	NA	5.53	130	NA	240	5	106	0.74	NS	NS	NS	NS	39	NS	0.07	ND	NS	NS	NS	9.5	0.59
DM 349D	Sep-97	NA	5.27	133	NA	241	6	100	1.93	NS	NS	NS	NS	35	NS	ND	ND	NS	NS	NS	8.6	1.3

<sup>g</sup> TOC = Total Organic Carbon.  
<sup>h</sup> °C = degrees Celsius.  
<sup>i</sup> su = Standard units.  
<sup>d</sup> µmhos/cm = micromhos per centimeter.  
<sup>e</sup> mg/L = milligrams per liter.  
<sup>f</sup> mV = millivolts.  
<sup>g</sup> NS = Not sampled.  
<sup>h</sup> NA = Not analyzed.  
<sup>i</sup> ND = Not detected.  
<sup>j</sup> <0.10 = measured at concentrations less than listed practical quantitation limit.  
<sup>k</sup> R = Rejected data.



**FIGURE 6**

## REDOX POTENTIAL ISOPLETH MAPS

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

Site SS27/XYZ

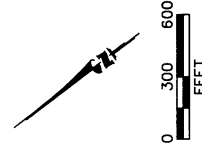
Site SS217ATZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

**Dover AFB, Delaware**

**PARSONS**  
**PARSONS ENGINEERING SCIENCE, INC.**  
Denver, Colorado

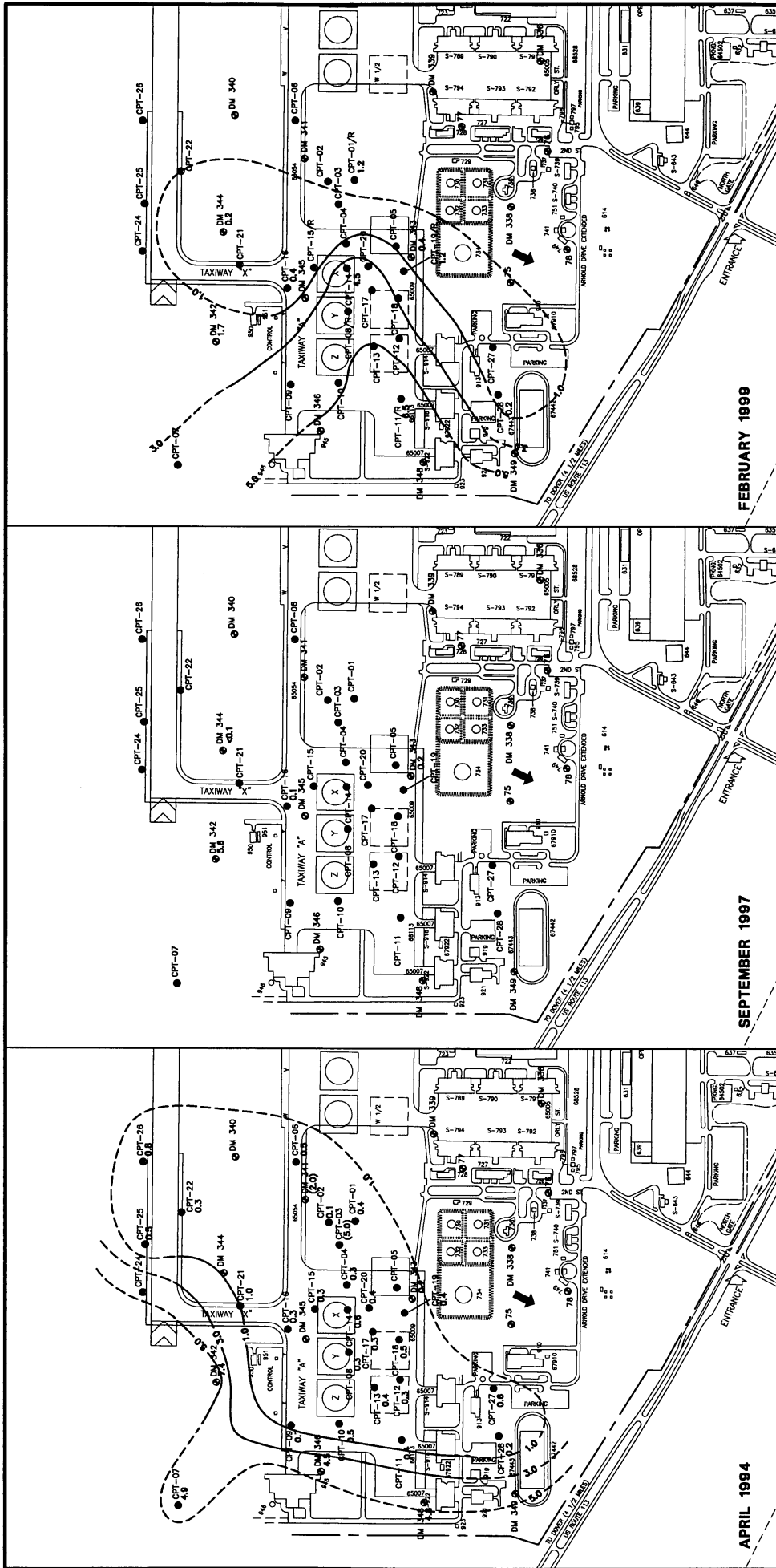
**Denver, Colorado**

**Denver, Colorado**



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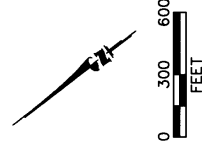
S:\ES\cod\AFCEE\729691\Dover\99dn0639.dwg, 08/24/99 at 13:12



**FIGURE 7**  
**DISSOLVED OXYGEN**  
**ISOPLETH MAPS**

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

**PARSONS**  
ENGINEERING SCIENCE, INC.  
Denver, Colorado



**LEGEND**

- DM 341 ● MONITORING WELL
- CPT-01 ● MONITORING POINT AND CPT TEST LOCATION INSTALLED BY CPT RIG.
- /R INDICATES REPLACEMENT WELL INSTALLED IN 1999
- ◻ FORMER C-10 FUELING PAD
- 0.2 DISSOLVED OXYGEN CONCENTRATION MILLIGRAMS PER LITER (mg/L)
- 1.0— DISSOLVED OXYGEN ISOPLETH (mg/L) (DASHED WHERE INFERRED)
- (5.0) DATA NOT USED TO DEVELOP CONTOURS
- ➔ APPROXIMATE GROUNDWATER FLOW DIRECTION

concentration measured at the site during the 1999 sampling event was 0.2 milligrams per liter (mg/L) at DM344, located in the BTEX source area, and also at CPT-28, located at the toe of the plume. Background DO concentrations measured across the site in April 1994 ranged from 4.9 mg/L to 7.4 mg/L for wells CPT-07 and DM342, respectively. In February 1999, background DO concentrations ranged from 4.5 mg/L (CPT-14) to 6.5 mg/L (CPT-11). Low DO concentrations relative to background DO in areas of elevated BTEX concentration indicates that aerobic respiration is a significant process of fuel hydrocarbon biodegradation at the site.

### 2.4.3 Ferrous Iron

Ferrous iron ( $\text{Fe}^{2+}$ ) is a byproduct of the anaerobic biodegradation process of ferric iron ( $\text{Fe}^{3+}$ ) reduction. Accumulation of ferrous iron in groundwater indicates that this microbially assisted process is or has occurred recently. Ferrous iron concentrations were measured at the site and are presented in Table 5. Ferrous iron concentration contour maps for April 1994, September 1997, and February 1999 are shown on Figure 8. Comparison of Figures 4 and 8 shows that areas with elevated BTEX concentrations also have elevated concentrations of ferrous iron.

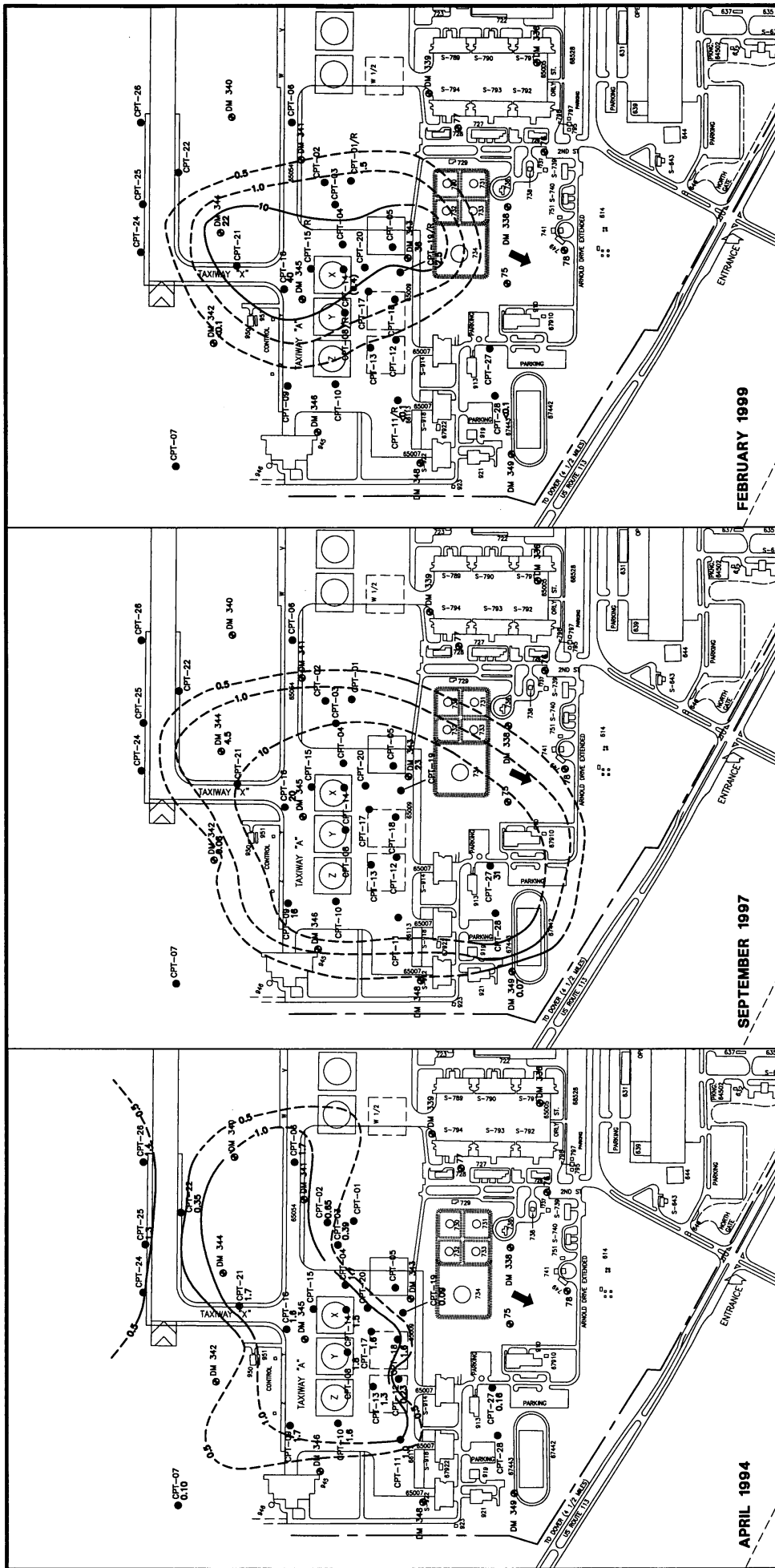
Concentrations of ferrous iron measured at the site in February 1999 ranged from less than 0.1 mg/L at CPT-28 to 40 mg/L at CPT-16. Ferrous iron concentrations show a general increase over time (from 1994 to 1999), with a notable increase at CPT-16 (1.6 mg/L in 1994 to 40 mg/L in 1999). Monitoring point CPT-16 is located near the center of the BTEX plume. The increase in ferrous iron concentration at this monitoring point appears to be a direct result of BTEX oxidation via iron reduction, since a marked decrease in BTEX concentration also was observed. The relationships implied by comparison of Figure 4 and Figure 8 suggest that the area of iron reduction is expanding with respect to elevated BTEX concentrations within the contaminant plume.

Recent evidence suggests that the reduction of ferric iron to ferrous iron cannot proceed without microbial mediation (Lovley and Phillips, 1988; Lovley *et al.*, 1991; Chapelle, 1993); therefore, the presence of ferrous iron strongly suggests that ferric iron is being used as an electron acceptor at the site. The coincident ferrous iron and BTEX plumes at Site SS27/XYZ indicates that the reduction of ferric iron to ferrous iron occurs during biodegradation of BTEX compounds. The general increase in ferrous iron from 1994 to 1999 further indicates that iron reduction is an ongoing process.

### 2.4.4 Nitrate + Nitrite

Nitrate and nitrite concentrations were measured separately in 1994, while nitrate + nitrite (as nitrogen) concentrations were measured during the 1997 and 1999 sampling events (Table 5). Concentration isopleth maps for nitrate + nitrite for April 1994, September 1997, and February 1999 are shown on Figure 9. The data for evaluating potential trends in nitrate + nitrite concentrations over time are limited. For February 1999, concentrations of nitrate + nitrite within the plume area ranged from less than 0.1 mg/L to 0.1 mg/L, while the one measurement outside of the contaminant plume





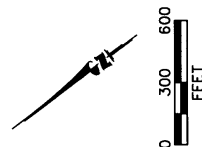
**FIGURE 8**

## FERROUS IRON ISOPLETH MAPS

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

**PARSONS**  
PARSONS ENGINEERING SCIENCE, INC.  
Denver, Colorado

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### LEGEND

DM 341  MONITORING WELL

CPT-01 ④ MONITORING POINT AND CPT  
TEST LOCATION INSTALLED  
BY CPT RIG.

/R INDICATES REPLACEMENT WELL

☒ FORMER C-10 FUELING PAD

0.16 DISSOLVED FERROUS IRON CONCENTRATION  
MILLIGRAMS PER LITER (mg/L)

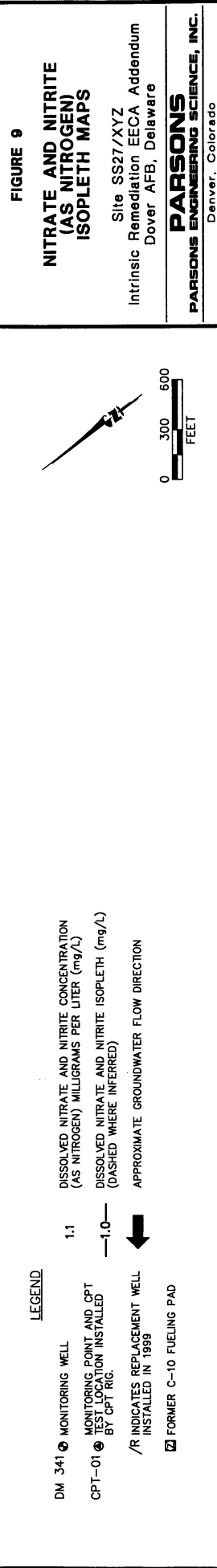
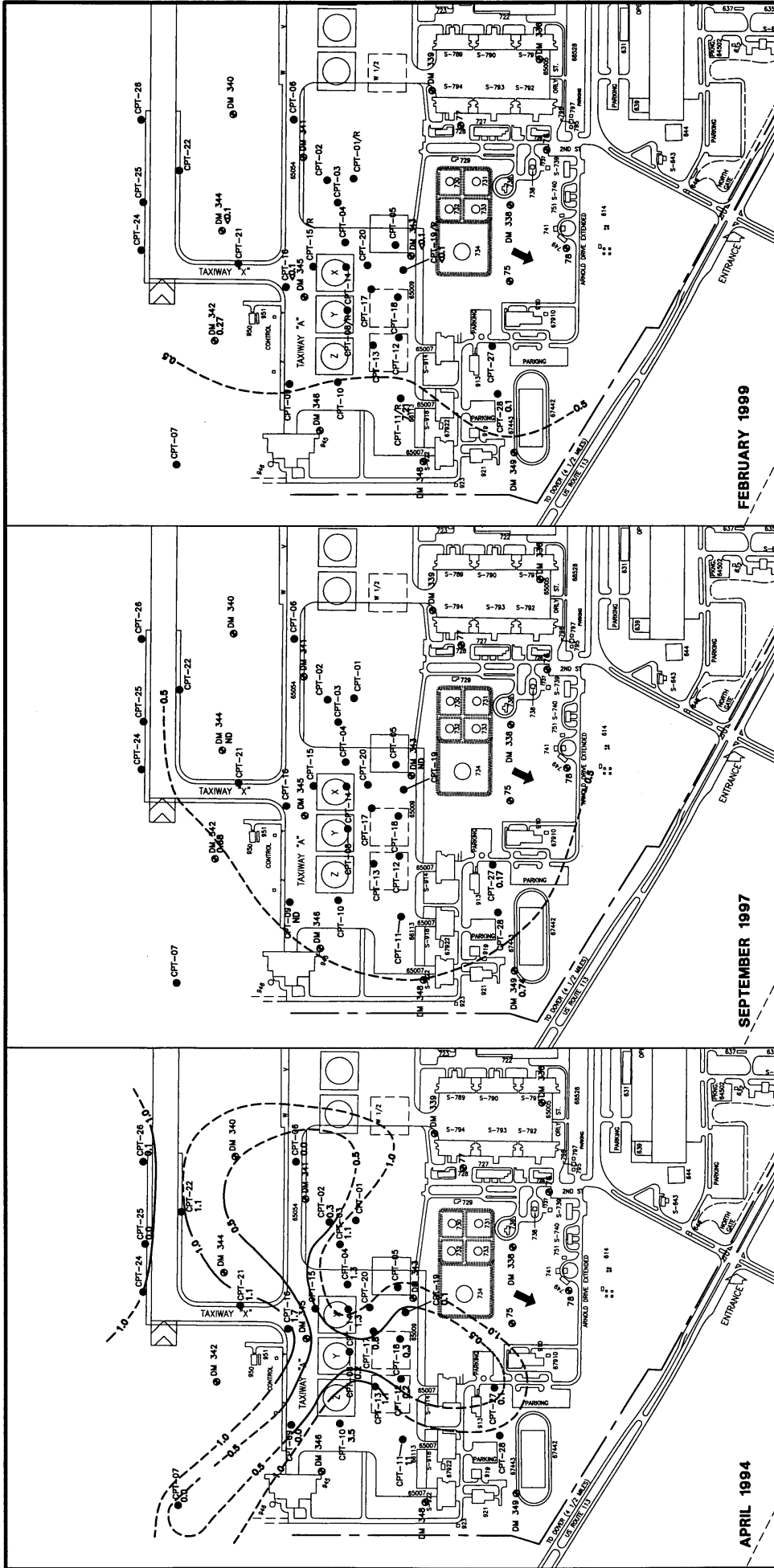
1.0— DISSOLVED FERROUS IRON ISOPLETH (mg/L)  
(DASHED WHERE INFERRED)

APPROXIMATE GROUNDWATER FLOW DIRECTION

APRIL 1994

**SEPTEMBER 1997**

FEBRUARY 1999



area shows a relatively higher background concentration of 7.21 mg/L (CPT-11). The low concentrations of nitrate + nitrite within the BTEX plume coupled with the relatively higher background concentrations of nitrate + nitrite indicate that anaerobic biodegradation of BTEX is occurring through the microbially mediated process of denitrification. However, the low concentration of nitrate in background groundwater, generally less than 10 mg/L, suggests that denitrification will be limited by the availability of nitrate as an electron acceptor.

#### **2.4.5 Sulfate**

Sulfate concentrations were measured during the April 1994, September 1997, and February 1999 sampling events (Table 5). The correlation of depleted sulfate concentrations with the highest BTEX concentrations provides strong evidence that anaerobic biodegradation of the BTEX compounds is occurring at the site through the microbially mediated process of sulfate reduction.

Concentrations of sulfate measured at the site during February 1999 ranged from 1.92 mg/L to 68.1 mg/L. Sulfate concentration contour maps for April 1994, September 1997, and February 1999 are shown on Figure 10. Comparison of Figures 4 and 10 shows that the areas with the elevated BTEX concentrations have depleted sulfate concentrations.

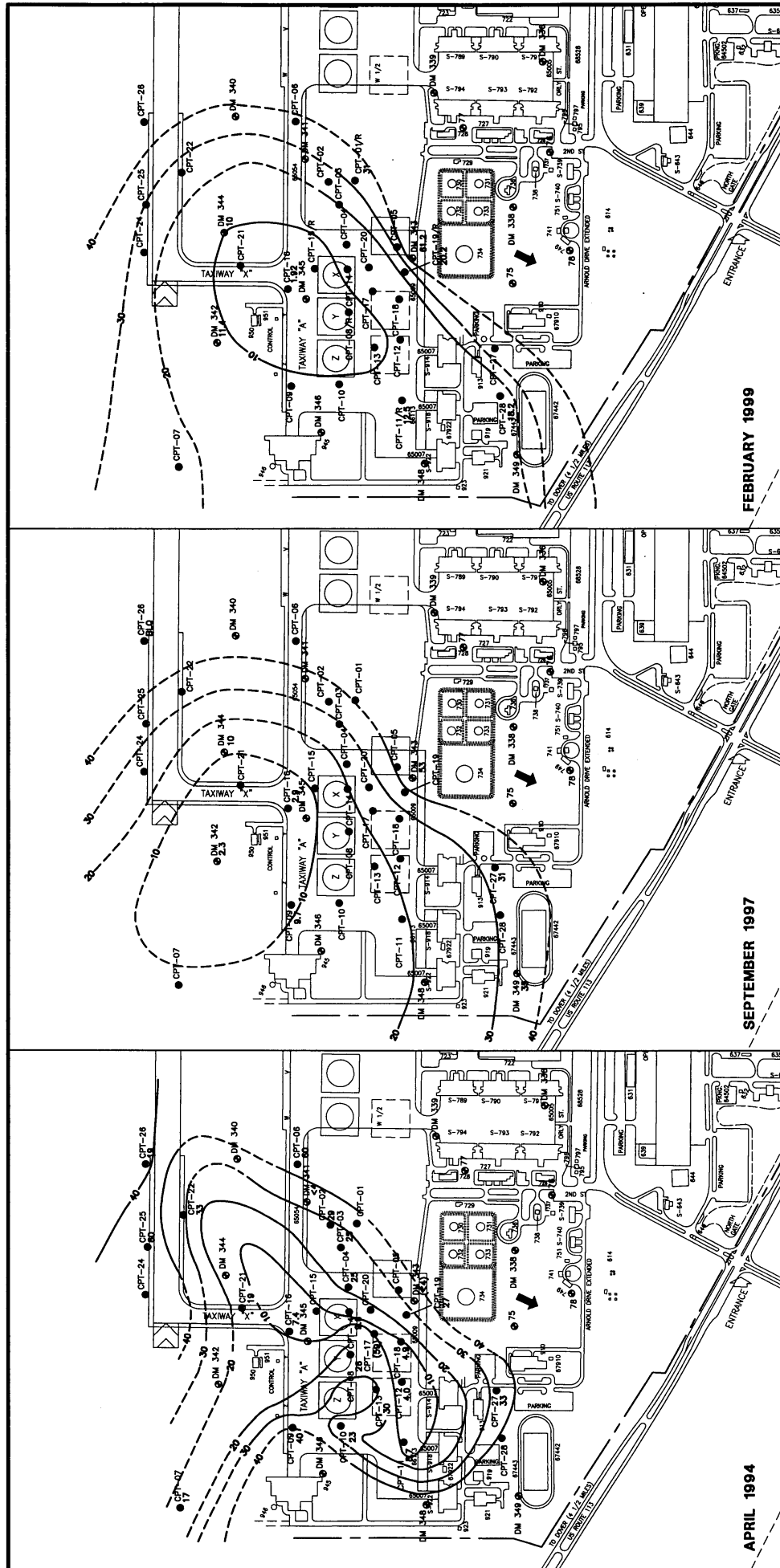
Concentrations of sulfate decreased from 1994 to 1999 at 5 locations, and increased at 4 locations. The area of depleted sulfate concentrations generally is centered about location CPT-16, which is centrally located within the BTEX plume. Notable decreases in sulfate concentrations occurred within the BTEX plume source area at well CPT-16 (7.4 mg/L to 1.92 mg/L) and in well DM344 (18 mg/L to 10 mg/L). The decrease in sulfate concentrations at these locations suggests that sulfate reduction has continued at the site, at least within the BTEX source area.

#### **2.4.6 Methane**

During methanogenesis, an anaerobic biodegradation process, carbon dioxide (or acetate) is used as an electron acceptor, and methane is produced. The presence of methane in groundwater is indicative of strongly reducing conditions and microbial degradation of fuel hydrocarbons. Elevated methane concentrations were detected in groundwater at Site SS27/XYZ during all sampling events (Table 5).

Methane solubility in water is approximately 24.4 mg/L at 25 degrees Celsius (Yalkowsky and Dannenfelser, 1992). During the April 1994 sampling event, reported laboratory concentrations exceeded methane solubility by several orders of magnitude. Therefore, the 1994 methane concentrations greater than approximately 24 mg/L may indicate the presence of "microsized" bubbles of methane gas in collected water samples. These data are not considered reliable in quantifying degradation due to methanogenesis at the site.

Methane concentrations in 1999 were elevated within the center of the BTEX plume, at concentrations less than the solubility limit of methane in groundwater at ambient temperatures. Methane concentrations for February 1999 are shown on Figure 11.



**LEGEND**

- DM 341 ● MONITORING WELL
- CPT-01 ● MONITORING POINT AND CPT TEST LOCATION INSTALLED BY CPT RIG.
- INDICATES REPLACEMENT WELL /R INSTALLED IN 1999
- FORMER C-10 FUELING PAD

**FIGURE 10**

**SULFATE ISOPLETH MAPS**

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

**PARSONS**  
PARSONS ENGINEERING SCIENCE, INC.  
Denver, Colorado

**APRIL 1994**

**SEPTEMBER 1997**

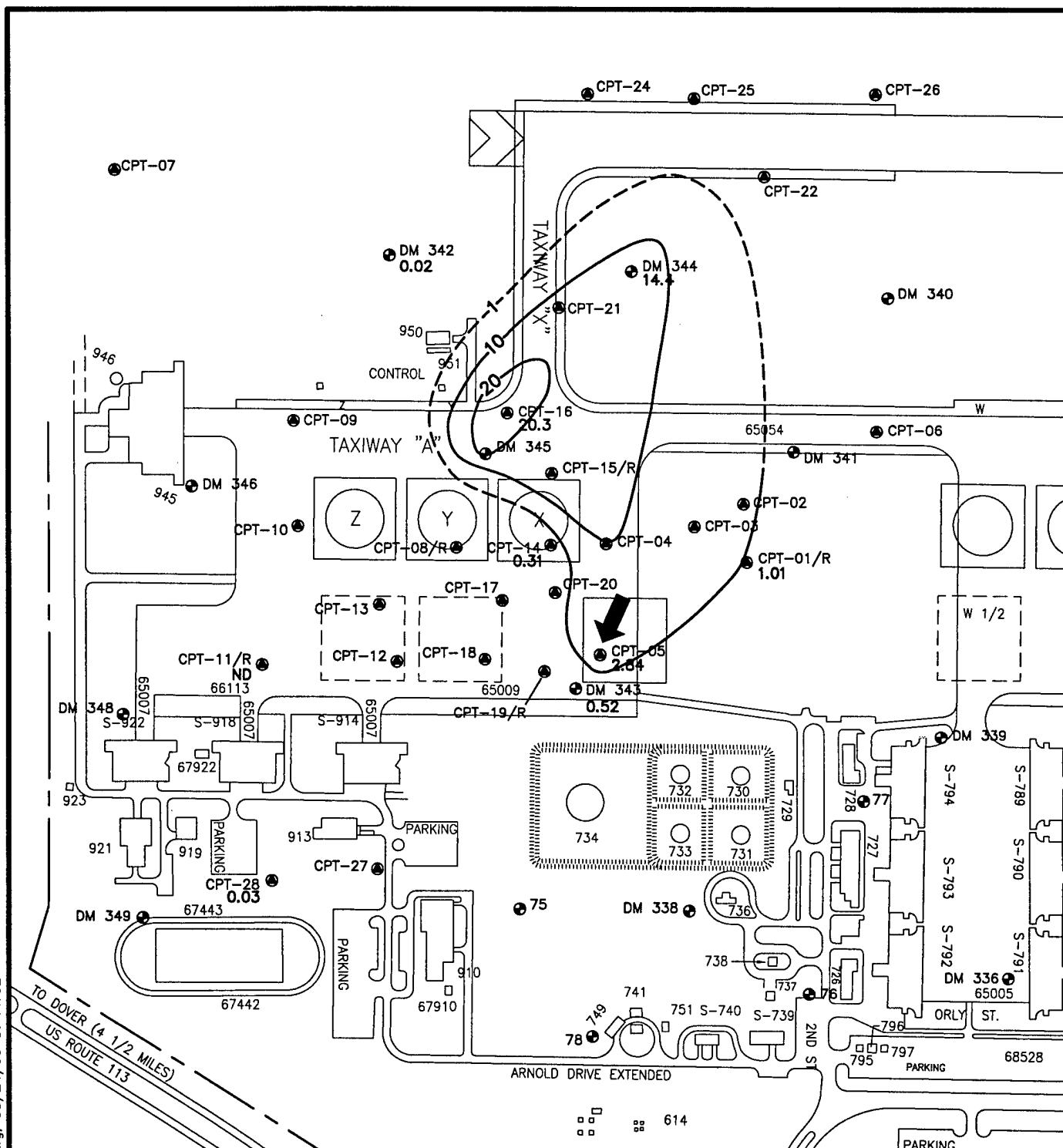
**FEBRUARY 1999**

**89** DISSOLVED SULFATE CONCENTRATION MILLIGRAMS PER LITER (mg/L)





**—10—** DISSOLVED SULFATE ISOPLETH (mg/L) (DASHED WHERE INFERRED)

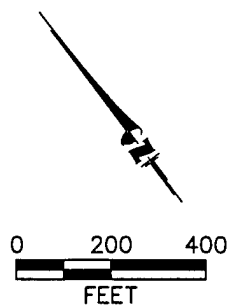
**(59)** DATA NOT USED TO DEVELOP CONTOURS

**➔** APPROXIMATE GROUNDWATER FLOW DIRECTION



### LEGEND

- DM 341  MONITORING WELL
- CPT-01  MONITORING POINT AND CPT  
TEST LOCATION INSTALLED  
BY CPT RIG.
- /R INDICATES REPLACEMENT WELL  
INSTALLED IN 1999
-  FORMER C-10 FUELING PAD
- 0.03 METHANE CONCENTRATION IN  
MILLIGRAMS PER LITER (mg/L)
- 1 — METHANE CONTOUR IN (mg/L)
- ND NOT DETECTED
-  APPROXIMATE GROUNDWATER  
FLOW DIRECTION

**FIGURE 11**

## METHANE ISOPLETH MAP

Site SS27/XYZ  
Intrinsic Remediation EE/CA Addendum  
Dover AFB, Delaware

**PARSONS**  
PARSONS ENGINEERING SCIENCE, INC.  
Denver, Colorado

The highest methane concentrations were detected at CPT-16 (20.3 mg/L) and DM344 (14.4 mg/L), located within the BTEX source area. Elevated methane concentrations coincident with elevated BTEX concentrations is a strong indicator that the microbially mediated process of methanogenesis is occurring at the site.

### **3.0 SUMMARY AND CONCLUSIONS**

Results from groundwater monitoring conducted during September 1997 and February 1999 indicate that natural attenuation of BTEX continues at Site SS27/XYZ. The areal extent of the BTEX plume does not appear to have increased since 1994; rather, the plume extent appears to be stable or diminishing slightly. The distribution of electron acceptors/metabolic byproducts that are involved in biologically mediated redox reactions indicate that these reactions continue to occur within the BTEX plume. Data suggest that degradation of dissolved BTEX at the site is occurring via the biodegradation processes of aerobic respiration, iron reduction, sulfate reduction, methanogenesis, and, to a lesser extent, denitrification.

Monitoring results indicate that the Bioplume II models presented in the EE/CA report (Parsons ES, 1996) overestimated both the overall size and the maximum concentration of dissolved BTEX that would be present in the plume over time.

While the extent of the BTEX plume has not increased, the continued presence of elevated dissolved BTEX concentrations suggests that both mobile and residual LNAPL persists in the groundwater and within the capillary fringe or saturated zone (i.e., a smear zone). A decrease in the average groundwater elevation of 5.7 feet from April 1994 to February 1999 has decreased the volume of groundwater in contact with saturated soil in the source area, potentially reducing the rate of BTEX mass flux to groundwater.

LTM should be continued to confirm stabilization of the dissolved BTEX plume and to document the continuing occurrence of microbially mediated biodegradation. LTM also is required to assess changes in groundwater elevation and the corresponding effect on dissolved BTEX concentrations or plume stability. An increase in groundwater levels would increase the volume of groundwater in contact with mobile or residual LNAPL, thereby potentially increasing the rate of mass flux of BTEX to groundwater. This could potentially reverse the observed decreasing trend in BTEX concentrations, and/or destabilize the dissolved BTEX plume.

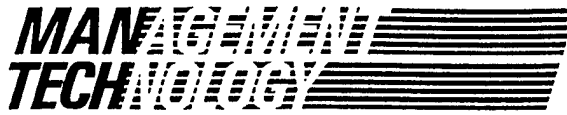
### **4.0 REFERENCES**

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**ATTACHMENT A**  
**ANALYTICAL RESULTS**  
**FEBRUARY 1999 AND SEPTEMBER 1997**





729691.00

Dover AFB

Update GW Analytical  
Data

Ref: 97-LP90/vg

September 24, 1997

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection & Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

Dear Don:

Attached are the results of time-sensitive parameters determined on field samples from Bolling AFB, Washington, DC and Dover AFB, Dover, DE. The analyses were performed between September 9 and 13 to satisfy Service Requests #SFTA-3-136 and SFTA-3-137.

The analyses were done using various Hach kits and meters provided on-site by Mr. Mike Cook. Please note that many samples had high levels of ferrous iron that interfered with CO<sub>2</sub> titrations; therefore, CO<sub>2</sub> was not determined for those samples.

Quality control data is reported for each day analyses were performed.

If you have any questions concerning this data, please feel free to contact me.

Sincerely,

*Lynda Pennington*  
Lynda Pennington

xc: R.L. Cosby  
G.B. Smith  
J.L. Seeley *JS*

ManTech Environmental Research Services Corporation

---

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

<u>Sample</u>	<u>pH</u>	<u>mV Redox</u>	<u>μS/cm</u> <u>Conductivity</u>	<u>mg/L</u> <u>(as CaCO<sub>3</sub>)</u> <u>Alkalinity</u>	<u>mg/L</u> <u>Ferrous Iron</u>	<u>mg/L H<sub>2</sub>S</u>	<u>ppm CO<sub>2</sub></u>
---------------	-----------	-----------------	-------------------------------------	--	------------------------------------	----------------------------	---------------------------

### 9-10-97 Quality Control

1413 Cond. Std.			1420				
7.00 pH Buffer	7.00						
Redox A		226					
Redox B		293					
2.0 mg/L Fe <sup>++</sup> Std.					2.04		
Fe <sup>2+</sup> Blank					0.00		
Alk. Std.				247			

Dover AFB, Dover, DE  
September 11-13, 1997

<u>Sample</u>	<u>pH</u>	<u>mV Redox</u>	<u>μS/cm</u> <u>Conductivity</u>	<u>mg/L</u> <u>(as CaCO<sub>3</sub>)</u> <u>Alkalinity</u>	<u>mg/L</u> <u>Ferrous Iron</u>	<u>mg/L H<sub>2</sub>S</u>	<u>ppm CO<sub>2</sub></u>
DM 343-S	5.75	-44.3	313	103	25.8	0.1	NA
DM 343-D	5.53	+107	259	45	22.8	<0.1	NA
DM-16S		----- FUEL ONLY		---	NO WATER RECOVERED	-----	
DM-16D	6.54	-34.8	384	213	19.8	<0.1	NA
DM-342S	6.01	+273	56	<1	0.06	NA	36
DM-342D	5.72	+261	57	12	0.06	NA	76
DM-344S	6.45	-58.0	456	236	4.50	1.0	NA
DM-344D	5.87	+129	113	32	5.25	NA	164
CPT-9	6.34	-133	755	397	15.5	0.3	NA
CPT-27D	5.33	+218	148	10	3.70	NA	370
CPT-27S	5.13	+275	195	<1	0.12	NA	160



Ref: 97-LH55

September 25, 1997

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection and Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

Dear Don:

As requested in Service Request #SF-3-280, gas analysis was performed for methane on samples from Dover AFB. The samples were received on September 16, 1997. The analyses were performed on September 17, 1997. These analyses were performed as per RSKSOP-194, and the calculations were done as per RSKSOP-175.

If you should have any questions, please feel free to contact me.

Sincerely,

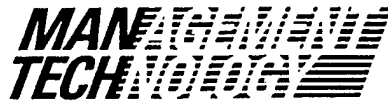
A handwritten signature in black ink, appearing to read "Lisa C. Hopkins". The signature is fluid and cursive, with a large initial "L" and "H".

Lisa Hopkins

xc: R.L. Cosby  
J.T. Wilson  
G.B. Smith  
J.L. Seeley *JS*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501



Ref: 97-SH65

September 22, 1997

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection & Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

Dear Don:

Attached are TOC results for 13 Dover liquids submitted September 19, 1997 under Service Request #SF-3-280. Sample analysis was begun September 22, 1997 and completed September 22, 1997 using RSKSOP-102.

Blanks, duplicates, and AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

Sincerely,

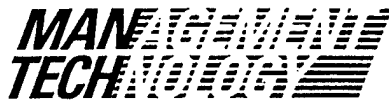
*Sharon Hightower*  
Sharon Hightower

xc: R.L. Cosby  
G.B. Smith  
J.L. Seeley *JS*

---

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501



Ref: 97-LB66  
September 18, 1997

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection and Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: Steve Vandegrift

Dear Don:

Please find attached the analytical results for the Dover AFB service request SF-3-280 requesting the analysis of ground water samples to be analyzed for benzene, toluene, ethylbenzene, p-, m-, and o-xylene, 1,3,5-, 1,2,4-, and 1,2,3-trimethylbenzene and total fuel carbon. We received your 15 samples, in duplicate, September 16, 1997 in capped, lead lined 40 mL VOA vials. The samples were analyzed on September 17-18, 1997. All samples were acquired and processed using the Millennium data system. A 4 point (1-500 ppb) external calibration curve was used to determine the concentration for all compounds.

RSKSOP-133 "Simultaneous Analysis of Aromatics and Total Fuel Carbon by Dual Column/Dual Detector Gas Chromatography in Ground Water Samples" was used for these analyses. Autosampling was performed using a Dynatech-Precision autosampler in-line with a Tekmar LSC 2000 sample concentrator.

Sincerely,

A handwritten signature in cursive script that reads "Lisa R. Black".

Lisa R. Black

xc: R.L. Cosby  
G.B. Smith  
J.T. Wilson  
J.L. Seeley

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501



Ref: 97-DK28/vg

October 8, 1997

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection and Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: S.A. Vandegrift ✓

Dear Dr. Kampbell:

This report contains the results of my GC/MSD analysis of one floating product sample, designated "16S", from Dover AFB, for Service Request #SF-3-280. The following compounds were quantitated: benzene, toluene, ethylbenzene, p-xylene, m-xylene, o-xylene, 1,3,5-trimethylbenzene (1,3,5-TMB), 1,2,4-trimethylbenzene (1,2,4-TMB), 1,2,3-trimethylbenzene (1,2,3-TMB), naphthalene, 2-methylnaphthalene and 1-methylnaphthalene.

The analytical method was a modification of RSKSOP-124. Cool on-column injection (0.1 µl) was used with electronic pressure control set for a constant flow of 1.0 ml/min. The capillary GC column consisted of a 30m X 0.25mm Restek Stabilwax (Crossbonded Carbowax-PEG, 0.5µm film) plus an SGE 0.2m X 0.53 mm ID deactivated Carbowax capillary precolumn. SIM mode GC/MSD was used with the ions chosen from those listed in EPA method 524.2 Revision 3.0, where available. Multiple ions were acquired and ion ratios used to verify the accuracy of target compound identification. Standards calibration ranged from 0.025 to 250 µg/ml and was divided into a low level (0.025 to 2.5 ug/ml) and high level (2.5 to 250 ug/ml) curve for improved quantitative accuracy. The sample was analyzed as a 1:40 methylene chloride dilution. Complete reports detailing the acquisition method and calibration curves have been recorded. The sample was received on October 6, 1997. SIM mode analyses for quantitation of target compounds was performed October 7, 1997.

The fuel product density was measured at 0.7485 g/ml.

If you require further information, please feel free to contact me.

Sincerely,

  
David A. Kovacs

xc: R.L. Cosby  
J.L. Seeley ✓  
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501



Ref: 97-LP98/vg  
97-MW57/vg

September 26, 1997

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection & Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: S.A. Vandegrift *SV*

Dear Don:

Attached are the results of 14 Dover AFB samples submitted to MERSC as part of Service Request #SF-3-280. The samples were received and analyzed September 17, 1997. The methods used for analysis were EPA Methods 353.1 for  $\text{NO}_2$  and  $\text{NO}_3$ , 350.1 for  $\text{NH}_3$ , and Lachat I.C. Method 10-511-00-1A for  $\text{Cl}$  and  $\text{SO}_4^{2-}$ . Quality assurance measures performed on this set of samples included spikes, duplicates, known AQC samples and blanks.

If you have any questions concerning these results, please feel free to contact us.

Sincerely,

*Lynda Pennington*  
Lynda Pennington

*Mark White*  
Mark White

cc: R.L. Cosby  
G.B. Smith  
J.L. Seeley *JS*

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

# Groundwater Sampling Record

Monitoring Well No. 16D

9-12-97

Dares AFB

## 5 [ ] SAMPLE EXTRACTION METHOD:

- [ ] Bailer made of: \_\_\_\_\_  
 [ ] Pump, type: \_\_\_\_\_  
 [ ] Other, describe: \_\_\_\_\_

Sample obtained is [X] GRAB; [ ] COMPOSITE SAMPLE

## 6 [ ] ON-SITE MEASUREMENTS:

Time	0825	0830	0835			Measured with
Temp (°C)	19.9	19.6	19.6			
pH						
Cond (µS/cm)						
DO (mg/L)	0.3	0.1	0.1			
Redox (mV)						
Salinity						

## 7 [ ] SAMPLE CONTAINERS (material, number, size):

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH \_\_\_\_\_  
 Items Cleaned (List): \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

2 [ ] PRODUCT DEPTH \_\_\_\_\_ FT. BELOW DATUM  
 Measured with: \_\_\_\_\_

WATER DEPTH 0.5 inch casing FT. BELOW DATUM  
 Measured with: \_\_\_\_\_

## 3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Color: \_\_\_\_\_  
 Turbidity: \_\_\_\_\_  
 Odor: \_\_\_\_\_  
 Other Comments: \_\_\_\_\_

## 4 [ ] WELL EVACUATION:

Method: \_\_\_\_\_  
 Volume Removed: \_\_\_\_\_  
 Observations: Turbidity (clear slightly cloudy very cloudy)  
 Water level (rose fell no change)  
 Water odors: \_\_\_\_\_  
 Other comments: \_\_\_\_\_

\*165 well  
 yielded fuel  
 only



Groundwater Sampling Record  
Monitoring Well No. DM343D

9-14-97

Dover AFB

5 [ ] SAMPLE EXTRACTION METHOD:

[ ] Bailer made of: \_\_\_\_\_  
[ ] Pump, type: \_\_\_\_\_  
[ ] Other, describe: \_\_\_\_\_

Sample obtained is [X] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Time	1650	1655	1700			Measured with
Temp (°C)	19.1	18.9	19.2			
pH						
Cond (µS/cm)						
DO (mg/L)	0.1	0.2	0.2			
Redox (mV)						
Salinity						

7 [ ] SAMPLE CONTAINERS (material, number, size): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH \_\_\_\_\_  
Items Cleaned (List): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2 [ ] PRODUCT DEPTH \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_  
WATER DEPTH 7 11.8' FT. BELOW DATUM  
Measured with: \_\_\_\_\_

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):  
Color: \_\_\_\_\_  
Turbidity: \_\_\_\_\_  
Odor: \_\_\_\_\_  
Other Comments: \_\_\_\_\_

4 [ ] WELL EVACUATION:  
Method: \_\_\_\_\_  
Volume Removed: \_\_\_\_\_  
Observations: Turbidity (clear slightly cloudy very cloudy)  
Water level (rose fell no change)  
Water odors: \_\_\_\_\_  
Other comments: \_\_\_\_\_

Groundwater Sampling Record  
Monitoring Well No. DM 3445

9-12-97  
Pmer #FB

5 [ ] SAMPLE EXTRACTION METHOD:

- [ ] Bailer made of: \_\_\_\_\_  
[ ] Pump, type: \_\_\_\_\_  
[ ] Other, describe: \_\_\_\_\_

Sample obtained is [X] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Time	1105					Measured with
Temp (°C)	18.7					
pH						
Cond (µS/cm)						
DO (mg/L)	0.0					
Redox (mV)						
Salinity						

7 [ ] SAMPLE CONTAINERS (material, number, size): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH \_\_\_\_\_  
Items Cleaned (List): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2 [ ] PRODUCT DEPTH \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_  
WATER DEPTH Product on Top \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):  
Color: \_\_\_\_\_  
Turbidity: \_\_\_\_\_  
Odor: \_\_\_\_\_  
Other Comments: \_\_\_\_\_

4 [ ] WELL EVACUATION:  
Method: \_\_\_\_\_  
Volume Removed: \_\_\_\_\_  
Observations: Turbidity (clear      slightly cloudy      very cloudy)  
Water level (rose      fell      no change)  
Water odors: \_\_\_\_\_  
Other comments: \_\_\_\_\_

Groundwater Sampling Record  
Monitoring Well No. DM 342D

9-12-97

Pomer AFB

5 [ ] SAMPLE EXTRACTION METHOD:

- [ ] Bailer made of: \_\_\_\_\_  
[ ] Pump, type: \_\_\_\_\_  
[ ] Other, describe: \_\_\_\_\_

Sample obtained is [X] GRAB; [ ] COMPOSITE SAMPLE

6 [ ] ON-SITE MEASUREMENTS:

Time	0955	1003	1008	1017		Measured with:
Temp (°C)	18.1	17.9	17.5	17.8		
pH						
Cond (µS/cm)						
DO (mg/L)	5.9	5.6	5.4	5.6		
Redox (mV)						
Salinity						

7 [ ] SAMPLE CONTAINERS (material, number, size): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

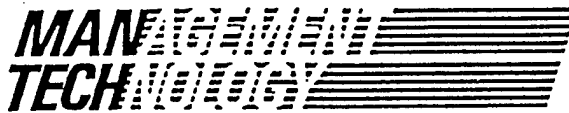
Check-off

1 [ ] EQUIPMENT CLEANED BEFORE USE WITH \_\_\_\_\_  
Items Cleaned (List): \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

2 [ ] PRODUCT DEPTH \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_  
WATER DEPTH 8.9 ft \_\_\_\_\_ FT. BELOW DATUM  
Measured with: \_\_\_\_\_

3 [ ] WATER-CONDITION BEFORE WELL EVACUATION (Describe):  
Color: \_\_\_\_\_  
Turbidity: \_\_\_\_\_  
Odor: \_\_\_\_\_  
Other Comments: \_\_\_\_\_

4 [ ] WELL EVACUATION:  
Method: \_\_\_\_\_  
Volume Removed: \_\_\_\_\_  
Observations: Turbidity (clear slightly cloudy very cloudy)  
Water level (rose fell no change)  
Water odors: \_\_\_\_\_  
Other comments: \_\_\_\_\_



MEMORANDUM

MANTECH ENVIRONMENTAL RESEARCH SERVICES CORP  
Environmental Science

In reply refer to : 98-SH15  
Contract #68-C-98-138

To: Dr. Don Kampbell

From: Sharon Hightower *SH*

Thru: Dennis Fine *DF*

Subject: SF-0-49

Date: March 8, 1999

Copies: R.L. Cosby  
G.B. Smith  
J.L. Seeley *WGL for JLS*  
L.K. Pennington *LKP*

Attached are TOC results for 12 Dover samples submitted March 1, 1999 under Service Request #SF-0-49. Sample analysis was begun March 4, 1999 and completed March 4, 1999 using RSKSOP-102.

Blanks, duplicates, and AQC samples were analyzed along with your samples, as appropriate, for quality control. If you have any questions concerning this data, please feel free to ask me.

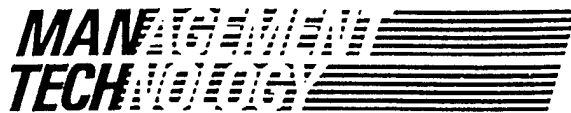
ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive  
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

KAMPBELL DOVER LIQUIDS SF-0-49  
SAMPLES RECEIVED 3/1/99  
SAMPLES ANALYZED 3/4/99 BY SHARON HIGHTOWER  
SAMPLES DATED 2/23/99

SAMPLE	% TOC
CPT-1	2.11
CPT-11SR	1.08
CPT-16D	4.32
CPT-19DR	2.87
CPT-28	1.42
DM342D	.893
DM342S	.970
CPT-343D	4.77
CPT-343S	5.77
CPT-344D	2.77
DUP	2.75
WP39	71.7
BLANK	<.4
CPT-344S	10.7
XD	1.31
5 MG/L	5.68
WP39	71.4

WP39 std. t.v.= 76.0 +/- 7.60



**MEMORANDUM**

**MANTECH ENVIRONMENTAL RESEARCH SERVICES CORP.**  
**Environmental Science**

**In reply refer to: 99-21LP/lp**  
**Contract # 68-C-98-138**

**To: Dr. Don Kampbell**

**Thru: D.D. Fine** *signature*

**From: Lynda Pennington** *LKP*

**Subject: SR # SF-0-49**

**Ref:**

**Copies: R.L. Cosby**  
**G.B. Smith**  
**J.L. Seeley** *signature*

**Date: March 10, 1999**

Attached are inorganic results for 12 Dover, Delaware groundwater samples submitted to MERSC under Service Request # SF-0-49. The samples were received March 1, 1999 and were analyzed March 3 and 4, 1999. The methods used were Waters capillary electrophoresis method N-601 for chloride and sulfate and Lachat FIA methods 10-107-04-2-A for nitrate plus nitrite and 10-107-06-1-A for ammonia.

Quality control measures performed along with your samples included analysis of blanks, duplicates, spikes, known WPO samples and check standards.

If you have any questions concerning this data, please feel free to contact me.

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ManTech Environmental Research Services Corporation

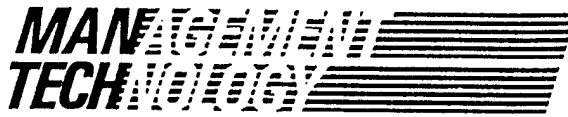
R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive  
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501

Rec'd March 1, 1999  
 Analyzed March 3 and 4  
 by L. Pennington

SF-0-49  
 Don Kampbell  
 Dover, DE

Page 1

Sample	Chloride (mg/L)	Sulfate (mg/L)	NO2+NO3(N) (mg/L)	Ammonia (mg/L)
CPT-1	3.63	31.0	<.10	<.10
CPT-11SR	1.01	12.5	7.21	<.10
CPT-16D	1.12	1.92	<.10	<.10
CPT-19DR	4.43	20.2	<.10	<.10
CPT-28	3.43	18.2	0.10	<.10
DM 342D	(0.98) (1.07)	(11.3) (11.4)	0.27	<.10
DM 342S	1.17	12.3	0.50	<.10
CPT 343D	5.31	68.1	<.10	0.12
CPT 343S	4.79	61.2	(<.10) (<.10)	(0.22) (0.22)
CPT 344D	1.38	14.0	<.10	<.10
CPT 344S	3.78	10.0	<.10	0.50
X-D	7.15	18.0	(<.10) (<.10)	(<0.10) (<.10)
Blank	<.50	<.50	<.10	<.10
WPO	10.9	59.0	11.4	5.15
WPO T.V.	10.8	58.0	12.0	4.80
Check Std.	5.40	5.05	1.08	1.00
Check Std. T.V.	5.00	5.00	1.00	1.00
Spike Recovery	102%	101%	93%	104%



**MEMORANDUM**

**MANTECH ENVIRONMENTAL RESEARCH SERVICES CORP.**  
**Environmental Science**

**In reply refer to: 99-AZ12**  
**68-C-98-138**

**To: Dr. Don Kampbell**

**Thru: Dennis Fine** *DFine*

**From: Amy Zhao**  
*A.Z.*

**Subject: SF-0-49**

**Date: March 10, 1999**

**Copies: R.L. Cosby**  
**G.B. Smith**  
**J.L. Seeley** *WGL for JLS*

As requested in Service Request #SF-0-49, gas analysis was performed for methane, ethylene and ethane from Dover AFB. The samples were received on March 1, 1999, and analyzed on March 5, 1999. Calculations were done as per RSKSOP-175. Analyses were performed as per RSKSOP-194.

If you have any questions concerning this data, please feel free to contact me.

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ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Center, P.O. Box 1198, 919 Kerr Research Drive  
Ada, Oklahoma 74821-1198 580-436-8660 FAX 580-436-8501



Sample	Methane ppm (Gas)	Methane ppm mg/L(Water)	Ethylene ppm (Gas)	Ethylene ppm mg/L(Water)	Ethane ppm (Gas)	Ethane ppm (Water)
100 ppm CH <sub>4</sub>	9.81E+01	~	**	~	**	~
100 ppm C <sub>2</sub> H <sub>4</sub>	**	~	9.58E+01	~	**	~
100 ppm C <sub>2</sub> H <sub>6</sub>	**	~	**	~	9.90E+01	~
HP. Helium Blank	~	**	~	**	~	**
Lab Blank	~	**	~	**	~	**
CPT-1(2-22)	~	1.01	~	**	~	**
CPT-11SR(2-22)	~	**	~	**	~	**
CPT-14D(2-22)	~	0.306	~	**	~	**
CPT-16D(2-22)	~	20.3	~	**	~	**
CPT-19DR(2-22)	~	2.84	~	**	~	**
CPT-19DR Lab Dup(2-22)	~	2.82	~	**	~	**
CPT-28(2-23)	~	0.029	~	**	~	**
CPT-343D (2-23)	~	0.131	~	**	~	**
CPT-343S (2-23)	~	0.523	~	**	~	**
CPT-344D (2-23)	~	2.29	~	**	~	**
CPT-344S (2-23)	~	14.4	~	0.004	~	**
CPT-344S Field Dup (2-23)	~	14.2	~	0.004	~	**
100,000 PPMCH <sub>4</sub>	9.44E+04	~	**	~	**	~
DM342D (2-23)	~	0.016	~	**	~	**
DM342S (2-23)	~	**	~	**	~	**
DM342S Field Dup (2-23)	~	**	~	**	~	**
10 PPM CH <sub>4</sub>	1.04E+01	~	**	**	**	~
10 PPMC <sub>2</sub> H <sub>4</sub>	**	~	9.20E+00	~	**	~
10 PPMC <sub>2</sub> H <sub>6</sub>	**	~	**	~	9.90E+00	~
1000 PPM CH <sub>4</sub>	1.05E+03	~	**	~	**	~
Lower Limit of Quantitation	10.0	0.001	10.0	0.003	10.0	0.002

Units for the samples are mg/L dissolved in water.

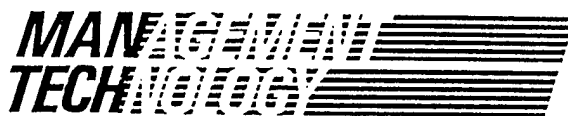
Units for the standards are parts per million.

sample date is represented in ( ), 1999.

\*\* denotes None Detected.

\* denotes Below Limit of Quantitation.

~ denotes Not Applicable.



Ref: 99-MB8  
Contract #68-C-98-138  
March 8, 1999

Dr. Don Kampbell  
National Risk Management Research Laboratory  
Subsurface Protection and Remediation Division  
U.S. Environmental Protection Agency  
P.O. Box 1198  
Ada, OK 74820

THRU: Dr. D. Fine *ditme*

Dear Don:

Please find attached the analytical results for Service Request # SF-0-49 requesting the analysis of aqueous samples from Dover AFB, DE to be analyzed for BTEXXX, TMB's and MTBE. The 12 samples plus duplicates were received in capped, 40 mL VOA vials on March 1, 1999. The samples were analyzed on March 5, 1999. All samples were acquired using the Millennium data system. A 5 point (1-1000 ppb) external calibration curve was used to determine the concentration for all compounds. Sample CPT-344S was diluted 1:10 with boiled milli-Q water.

RSKSOP-122 "Analysis of Volatile Aromatic Hydrocarbons with Separation of Xylene Isomers by Purge & Trap Gas Chromatography" was used for these analyses. Auto-sampling was performed using a Dynatech Precision autosampler system in line with a Tekmar LSC 2000 concentrator.

Sincerely,

*Mark Blankenship*

Mark Blankenship

xc: R.L. Cosby  
J.L. Seeley *WGL for JLS*  
G.B. Smith

ManTech Environmental Research Services Corporation

R.S. Kerr Environmental Research Laboratory, P.O. Box 1198, 919 Research Drive  
Ada, Oklahoma 74821-1189 405-436-8660 FAX 405-436-8501

SAMPLE NAME	MTBE	BENZENE	TOLUENE	ETHYLBENZENE	P-XYLENE	m-XYLENE	O-XYLENE	1,3,5-TMB	1,2,4-TMB	1,2,3-TMB
10 PPB STD	10.2	9.5	9.2	10.1	9.5	9.6	9.1	10.0	9.5	9.2
20 PPB QA/QC STD	20.9	18.5	18.3	18.8	19.1	18.9	18.4	20.4	19.5	18.0
CPT-1	ND	BLQ	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	ND
CPT-113R	ND	ND	BLQ	ND	ND	BLQ	ND	ND	ND	ND
CPT-14D	185	12.6	21.7	4.9	4.7	11.8	4.6	2.3	7.7	3.3
CPT-16D	3.1	587	4.3	232	2.5	3.1	5.0	7.0	1.2	10.9
CPT-19DR	333	34.8	12.6	4.4	6.8	5.0	7.0	3.0	6.1	BLQ
CPT-28	1.1	BLQ	BLQ	ND	ND	ND	ND	ND	ND	ND
10 PPB STD	10.2	9.5	9.4	10.4	9.8	9.8	9.3	10.2	9.6	9.3
DM-342D	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DM-342S	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CPT-343D	15.3	ND	BLQ	ND	ND	BLQ	ND	ND	ND	ND
CPT-343S	35.9	BLQ	BLQ	BLQ	BLQ	BLQ	ND	ND	BLQ	ND
CPT-343S LAB DUPLICATE	34.1	ND	BLQ	BLQ	BLQ	BLQ	ND	ND	BLQ	ND
CPT-344D	7.5	7.6	BLQ	2.8	BLQ	BLQ	ND	2.1	BLQ	BLQ
CPT-344S	22.7	2010	198	447	722	1370	549	238	796	302
GC LAB BLANK	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = None Detected; BLQ = Below Limit of Quantitation, 1 ppb.

Analyzed 3/5/99

# Water Quality Analyses - Dover AFB - February 1999

Sample	Alkalinity mg/L	Ferrrous Iron mg/L	Sulfide mg/L	Free CO <sub>2</sub> mg/L
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CPT-115R	40	<.1	<.1	10
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CPT-19DR	120	2.5	<.1	50
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DM-383S	Dry well			
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CPT-1	20	1.5	<.1	50
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CPT-145	No yield well			
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CPT-14D	Too Turbid	0.4	<.1	Turbid
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DM-342D	20	0.1	<.1	5
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DM-342S	20	<.1	<.1	5
---------	----	-----	-----	---

CPT-28	20	<.1	<.1	50
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CPT-155R	No yield well			
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DM-345	Flush mount cavity filled with water			
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CPT-16D	200	40.	0.1	100
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DM-344S	240	22.	0.4	40
---------	-----	-----	-----	----

DM-344D	100	4.0	0.1	40
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DM-343S	40	30.	0.1	170
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DM-343D	20	35.	0.1	120
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P/R

Note: Water table down because of a dry part year.

5527/K12

## Water Quality Analyses - Dover AFB - February 1999

Sample	Temp °C	pH	Cond µS/cm	DO mg/L	Redox mV	Notes	DT Toc
DM-344S	12.3	6.4	439	0.2	N.D.	Floating Product	13.5
DM-343S	10.3	5.6	195	2.0	N.D.		14.9
DM-344D	12.0	6.2	235	0.6	N.D.		10.0
CPT-16D	15.1	6.4	325	0.4	+147		12.2
CPT-15SR	—	—	—	—	—	No water yield - fuel in dribbles	13.2
DM-342S	8.8	5.6	89	1.7	+134		11.7
CPT-14D	14.3	—	108	4.5	+84	Low yield	15.5
CPT-1	13.0	5.6	149	1.2	+80		14.1
CPT-14S	—	—	—	—	—	Dry well 2 <sup>nd</sup> mud	—
DM-342D	13.0	5.7	62	3.2	+139		11.5
CPT-28	15.1	5.7	101	0.2	+120		16.1
DM-34S	—	—	—	—	—	well cavity flooded	—
DM-383S	—	—	—	—	—	No water yield	16.5
CPT-11SR	11.0	5.8	125	6.5	+109		13.4
CPT-19DR	13.6	6.3	362	1.2	+11		15.4
DM-343D	16.0	5.6	232	0.4	N.D.		14.9

P.K.

**ATTACHMENT B**  
**RESPONSES TO COMMENTS**

# PARSONS

Parsons Engineering Science, Inc. • A Unit of Parsons Infrastructure & Technology Group Inc.

1700 Broadway, Suite 900 • Denver, Colorado 80290 • (303) 831-8100 • Fax: (303) 831-8208 • www.parsons.com

20 September 1999

Mr. Jerry Hansen  
Technical Program Manager  
AFCEE/ERT  
3207 North Road, Bldg. 532  
Brooks AFB, TX 78235-5363

Subject: Responses to AFCEE Comments on the Draft Intrinsic Remediation Engineering Evaluation/Cost Analysis Addendum for Site SS27/XYZ, Dover AFB, Delaware (Contract F41624-92-D-8036-0025)

Dear Mr. Hansen:

This letter provides responses to comments received on the Draft Intrinsic Remediation Engineering Evaluation/Cost Analysis (EE/CA) Addendum for Site SS27/XYZ, Dover Air Force Base (AFB), Delaware. This draft EE/CA was prepared by Parsons Engineering Science, Inc. (Parsons ES) for the Air Force Center for Environmental Excellence Technology Transfer Division (AFCEE/ERT) and Dover AFB. The intent of the addendum was to evaluate changes in concentrations and the extent of groundwater contaminated with fuel hydrocarbons at Site SS27/XYZ. The draft addendum was submitted to AFCEE in August 1999. Comments on the draft report were received from AFCEE as reviewed by Mr. Jon Atkinson of AFCEE, dated 17 September 1999. Responses to these comments were prepared by Parsons ES and are presented herein.

## GENERAL COMMENTS

Comment 1) Page 3, Sec 1.2, Para 2, Sent 5: Although this sentence states that JP-4 fuel is currently used at the Base, my understanding is that the Air Force has not used JP-4 for several years. Consequently, this sentence may need to be revised accordingly.

Parsons ES Response: *JP-4 was in use at the time that fuel leaks were detected at Site SS27/XYZ. Any reference to current use of fuel at the site will be limited to "jet fuel" in general.*



Comment 2) Pages 6 and 7, Tables 1A and 1B: For the analyte Alkalinity, the typo "Biocarbonate" needs to be corrected.

Parsons ES Response: *The text will be corrected as indicated.*

Comment 3) Page 9, Sec 2.1, Para 3, Sent 3: Recommend reporting hydraulic conductivity in units of ft/day, because they are more commonly used than ft/min.

Parsons ES Response: *Hydraulic conductivity will be reported in units of feet per day (ft/day) as recommended.*

Comment 4) Page 15, Sec 2.1, Para 1, Last Sent: To correct terminology, suggest changing "groundwater table" to "water table."

Parsons ES Response: *The text will be corrected as indicated.*

Comment 5) Page 21, Sec 2.3, Para 2: Here, and throughout the document, recommend reporting analytical results to no more than three significant figures to better reflect the accuracy and precision of these measurements.

Parsons ES Response: *Analytical results will be reported to no more than three significant figures throughout the document as recommended.*

Comment 6) Pages 22, Fig 5: To enhance readability, suggest placing the log scale on the right-hand y-axis also.

Parsons ES Response: *The log scale will be placed on the right-hand y-axis as suggested.*

Comment 7) Page 23, Sec 2.4, Para 2: Suggest adding manganese to the list of electron acceptors.

Parsons ES Response: *Manganese will be added to the list of electron acceptors as suggested.*



Mr. Jerry Hansen  
20 September 1999  
Page 3

Comment 8) Pages 23 and 24, Sec 2.4, Para 3, Sent 1: The typo "hat" needs to be corrected.

Parsons ES Response: *The typo will be corrected to "that."*

Comment 9: Pages 35 and 37, Sec 3.0, Last Sent: Recommend stating whether or not PES believes that manganese reduction is occurring at the site.

Parsons ES Response: *Manganese was not analyzed by the USEPA NRMRL during any of the sampling events (April 1995, September 1997, and February 1999). Therefore, Parsons ES can not state whether manganese reduction is occurring at the site.*

Comment 10) Page 37, Sec 3.0, Para 2, Line 3: Suggest changing "persists on" to "persists in."

Parsons ES Response: *The text will be changed as suggested.*

If you have any questions, have additional comments, or require additional information, please call me at (303) 831-8100.

Sincerely,

PARSONS ENGINEERING SCIENCE, INC.

*Bruce M. Henry*

Bruce M. Henry, P.G.  
Project Manager

cc: File 729691.06000